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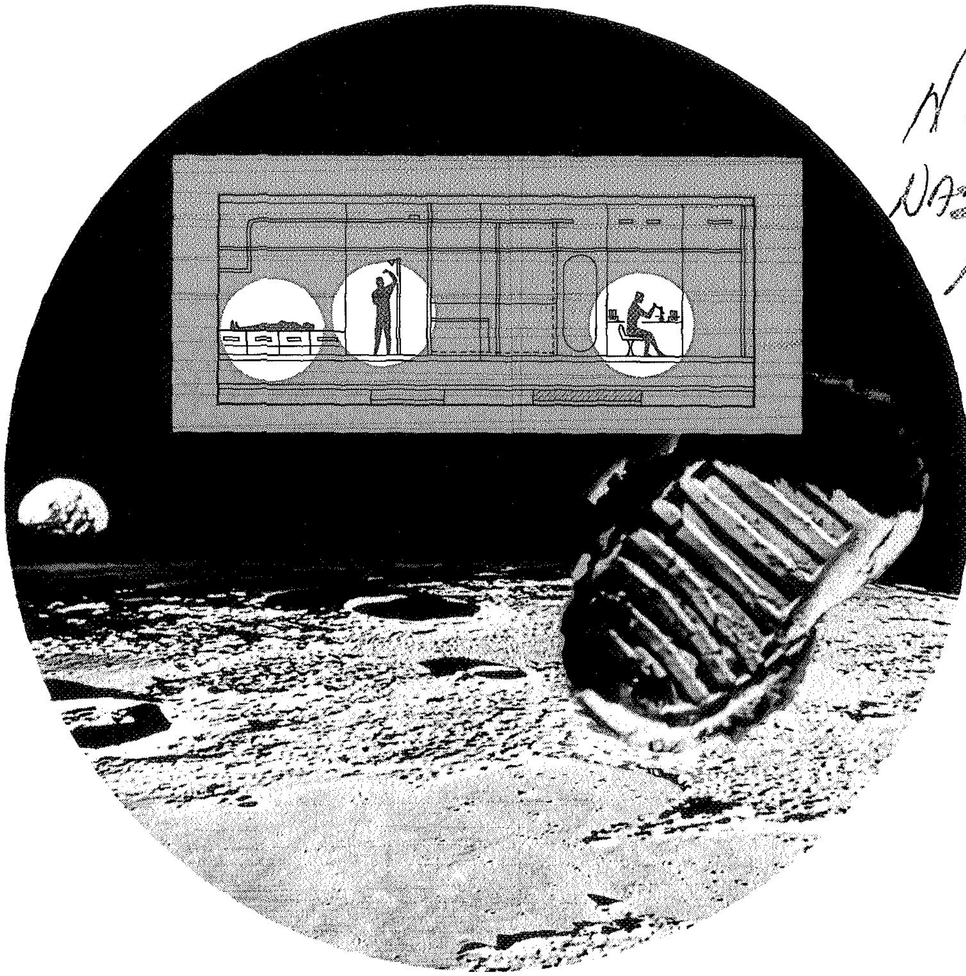

ORBITING LUNAR STATION (OLS)

PHASE A FEASIBILITY AND DEFINITION STUDY

VOLUME VI

COMPARISON OF OLS CONFIGURATIONS

FINAL REPORT

CASE FILE COPY

Space Division
North American Rockwell

APRIL 1971
Prepared by Advanced Program Engineering

12214 Lakewood Boulevard, Downey, California 90241

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ORBITING LUNAR STATION PHASE A FEASIBILITY AND DEFINITION STUDY

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COMPARISON OF OLS CONFIGURATIONS

(FINAL REPORT)

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Approved By

L. R. Hogan

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SPACE DIVISION
NORTH AMERICAN ROCKWELL CORPORATION

FOREWORD

This report contains the results of North American Rockwell's analyses conducted under the Orbiting Lunar Station Feasibility and Definition Study (Phase A), Contract NAS9-10924, in accordance with line item 5 of the Data Requirements List (DRL5).

This report is compiled in six volumes for ease of presentation, handling, and readability of the data in the report. In general, each volume is a compilation of the data generated in a specific phase of the study.

This is Volume VI of the report and contains configuration comparisons between the representative and derivative OLS configurations, and cost and schedule projections for the two OLS configurations.

The documents comprising the study report are:

Volume I	OLS Objectives
Volume II	Mission Operations and Payloads Analysis
Volume III	OLS Performance Requirements
Volume IV	OLS Configuration and Systems Analysis
Volume V	OLS Configuration Definition
Volume VI	Comparison of OLS Configurations

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The following persons have participated in the comparison of OLS configurations and the development of OLS cost and schedule projections, and have contributed to the preparation of this report:

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J. V. Murphy	Development Test Requirements
W. H. Wolfinger	Cost Analysis
G. S. Frassinelli	Cost Analysis

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ILLUSTRATIONS

TABLES

1.0 INTRODUCTION AND SUMMARY

This volume is comprised of the following major divisions: 2.0, OLS Configuration Comparison; 3.0, Representative Configuration Cost and Schedule; and 4.0, Derivative Configuration Cost and Schedule. A detailed definition of, and the design selection rationale for, the representative and derivative configurations upon which this volume is based, are presented in Sections 2.0, 3.0, and 7.0 of Volume V, respectively.

1.1 OLS CONFIGURATION COMPARISON

Presented in Section 2.0 are three major categories of comparisons between the representative OLS configuration and the derivative OLS configuration. These comparisons are: 2.1, Performance Comparison; 2.2, Schedule Comparison; and 2.3, Cost Comparison. Section 2.1 identifies and compares the differences in performance and operational capabilities of two OLS configurations, and is subdivided into Subsystems, Mission Operations, and Safety/Escape/Rescue. Section 2.2 includes comparisons of the gross characteristics, the test articles required, and the development schedules. Section 2.3 presents a comparison of both annual and cumulative funding requirements.

1.2 REPRESENTATIVE CONFIGURATION COST AND SCHEDULE

Section 3.0 presents the development of the representative OLS cost and schedule data. A hardware tree, test requirements, test articles, hardware utilizing list, facility requirements, program schedule, work breakdown structure, and program cost estimates for Phases C and D are presented.

1.3 DERIVATIVE CONFIGURATION COST AND SCHEDULE

Section 4.0 presents the comparable data for the derivative OLS that were presented in Section 3.0 for the representative OLS. Some of the data in Section 3.0 are intentionally duplicated in Section 4.0 in order to present a more complete and independent data package for each OLS configuration. References to a previous section are minimized.

2.0 OLS CONFIGURATION COMPARISON

2.1 PERFORMANCE COMPARISON

Presented in this Section is a comparison of performance and operational capabilities of the representative and derivative OLS configurations as defined in Sections 2.0, 3.0, and 7.0 of Volume V, respectively. The presentation of performance comparisons is divided into the following three categories: 2.1.1, Subsystems; 2.1.2, Mission Operations; and 2.1.3, Safety, Escape, and Rescue.

2.1.1 Subsystems

In this Section, the performance capabilities of the representative and derivative OLS subsystems are compared. Both of the OLS configurations are designed to meet the requirements defined in Section 7.0 of Volume III. Consequently, the performance capabilities of the respective subsystems in the two configurations are, in many respects, identical. In the following paragraphs, only those areas in which significant differences in performance capability exist will be discussed.

Structures

The dry weight of the representative OLS core module is 85,155 pounds; this does not include the weight of the power module or the experiment module. The dry weight of the modules which make up the comparable portion of the derivative OLS is 137,250 pounds. Major contributors to this 52,000-pound weight difference are:

1. Structural weight of the derivative OLS modules in question, all except the power and experimental modules, exceeds that of the representative OLS core module structural weight by 13.8K pounds.

2. Derivative OLS Environmental Protection Subsystem (ENPS) dry weight totals 2.4K pounds more due principally to the greater surface area of the derivative configuration.

3. Derivative OLS Reaction Control Subsystem (RCS) dry weight totals 2.4K pounds more due to the unneeded RCS equipment located in the mated ends of derivative OLS core modules 1A and 1B.

4. Derivative OLS Electrical Power Subsystem (EPS) dry weight totals 12.4K pounds more due to the increase in the weight of the power conditioning and control equipment, wiring, and primary batteries, which are located in modules other than the power module.

5. Derivative OLS Information Subsystem (ISS) dry weight totals 0.8K pounds more due to the decentralized ISS concept employed on the derivative OLS as contrasted to the centralized multi-processor computer concept employed on the representative OLS.

6. Derivative OLS Environmental Control and Life Support Subsystem (ECLSS) dry weight totals 7.2K pounds more on the derivative OLS.

7. Docking provisions dry weight of the derivative OLS exceeds that of the representative OLS by 9.0K pounds. This difference is due primarily to the seven side-docking functional modules which are unique to the derivative configuration, and to the additional core module assembly docking ports required to accommodate these seven modules.

8. Personnel provisions dry weight of the derivative OLS exceeds that of the representative OLS by 1.4K pounds due primarily to the additional weight of ladders, rails, mobility aids, etc., required.

The modular nature of the derivative OLS is advantageous in that it is more adaptable to modification through module substitution. However, at the same time transport of bulky pieces of cargo within the station is more difficult. Also the modular concept is less desirable from a crew/habitability standpoint due to the more compartmentized, less centralized layout of facilities. The five modules which constitute the primary living and operational quarters of the derivative OLS have a combined gross pressure volume of $\approx$ 24K cubic feet as contrasted to $\approx$ 20K cubic feet for the four-deck representative OLS.

The representative OLS is adaptable to an artificial g environment station as described in Section 2.0 of Volume V. The derivative OLS however would require extensive structural modification to enable the assemblage of modules to be rotated at the end of a boom attached to a zero g hub due to the loads and moments induced at junctions of the individual modules with the core modules.

Environmental Control/Life Support Subsystem (ECLSS)

The major difference between representative and derivative OLS ECLSS performance requirements is in oxygen/nitrogen leakage. The representative OLS O_2/N_2 leakage is 24 pound/day while the derivative OLS O_2/N_2 leakage is 52 pound/day. The difference between the two leakage rates is directly attributable to the difference between the representative and derivative OLS configurations.

The prime contributor to O_2/N_2 leakage (seal leakage), is configuration sensitive. The representative OLS has six 5-foot docking ports which make up the majority of the leakage. The derivative OLS has nineteen 5-foot docking ports.

The difference between the representative and derivative OLS O_2/N_2 leakage impacts the RCS cryogenic nitrogen storage requirements. Cryogenic storage of nitrogen for 180 days on the representative OLS amounts to 3551 pounds, whereas it is 7349 pounds on the derivative. Of these totals, 455 pounds of N_2 is for subsatellite provisions, while the rest is for leakage makeup and metabolic consumption. Cryogenic oxygen storage requirements are determined by 109 days of normal operations (ECLSS and RCS) plus contingency provisions (see RCS discussion).

Electrical Power Subsystem (EPS)

In Volume V, it is determined that in spite of the difference between MSS and OLS EPS performance requirements, the 25 kw capacity 12-man MSS EPS could be employed as the derivative OLS EPS without modification. As a result, the derivative OLS EPS has a higher initial weight, cost, maintenance and resupply weight than the representative OLS EPS. Representative and derivative OLS EPS weight and relative costs are given in subsections 3.2 and 7.3 of Volume V.

Aside from the excess capability of the MSS EPS to meet the OLS power requirements, the major difference between the representative and derivative OLS EPS is in the energy storage concepts. The representative OLS chose regenerative fuel cells over the battery-battery charger energy storage concept because of their lower weight, volume, resupply, heat rejection, maintenance and cost. To minimize the modification of the MSS to perform lunar orbit operations, the derivative OLS retained the 10,165 pounds of secondary MSS batteries for energy storage. In addition to the secondary batteries, the derivative OLS requires 3740 pounds of primary batteries to supply power prior to solar array deployment.

As pointed out in the thermal protection discussion of ENPS, the power module coolant loop of the derivative OLS must be divided between the batteries and the power conditioning equipment. To maintain the batteries at 50F, the battery coolant loop must be connected to the loop of the other OLS modules through a heat pump. No such complexity exists in the representative OLS power module thermal control system because of the use of regenerative fuel cells.

Information Subsystem (ISS)

There is a significant difference in the method by which the OLS ISS requirements are implemented on the representative and derivative configurations. The modular concept of the derivative OLS does not lend itself to the monolithic central computer (multiprocessor) concept of the integrally-launched representative OLS. Instead, the centralized computer concept has been divided into decentralized modular processors (central, local and preprocessor) which effectively introduce a hierarchy of processing.

The capabilities of the representative and derivative OLS ISS (as described in subsections 3.3 and 7.4 of Volume V) are essentially identical. All the features of the representative OLS in terms of safety, maintenance, commonality, flexibility and operational availability have been retained in the derivative OLS with the additional feature of less implementation complexity. In general, derivative OLS ISS assembly weight and power requirements are somewhat greater than those of the representative OLS ISS, but this is not expected to be of significance since only small increments of the total station weight are launched from earth at a given time.

The major difference between the representative and derivative OLS ISS, aside from those which are due to the modular concept, occurs in the configuration of the external communications. The representative OLS employs phased arrays while the derivative OLS employs three 5-foot, high-gain parabolic antennas. A comparison of the two high-gain antenna concepts in Table 2-1 indicates that the initial development and cost of the phased arrays are more than balanced by their increased performance. Parabolic antennas are used on the derivative OLS to minimize the required modifications of the MSS for lunar orbit operations.

Table 2-1. Representative and Derivative OLS High-Gain Antenna Comparison

PARABOLAS	ARRAYS
INSTALLATION Must Be Deployed-- Clear of Obstructions Rigidity Req'd For Tracking	Deployment Limited To Element Above Solar Array Requires Allocation Of Surface Area
OPERATION One Target Per Antenna Mechanical Movement Affects SCS Gimbals Require Periodic Maintenance Software Minimal For Tracking	Multiple Target Capability No Mechanical Movement No Periodic Maintenance - Graceful Degradation Continuous Software Support For Track
WEIGHT Light Antennas- Heavy Deployment Structure ($\approx$ 720 lb)	Weight Less Than Parabola-Boom Combination ($\approx$ 335 lb)
COST Moderate	Moderate to High
DEVELOPMENT RISK Low	Moderate

Guidance and Control (G&C)

The configuration for the Guidance and Control subsystem of the derivative OLS is identical to that of the representative OLS with the exception of the CMG array. The derivative OLS employs the 3000-foot-pound-seconds CMG's of the MSS weighing 1600 pounds. The representative OLS employs 2700-foot-pound-seconds CMG's weighing 1520 pounds. Control mement gyro 180 day desaturation impulse on the derivative OLS is 61,000 lb-sec less than that of the representative OLS, resulting in a requirement for 2600-foot-pounds-seconds CMG's weighing 1500 pounds. The heavier MSS CMG's were selected to save the cost of development and qualification for the lighter CMG's.

Reaction Control Subsystem

The RCS impulse requirements for 180 days of normal operations are significantly different between the representative and derivative OLS configurations. Total representative OLS RCS impulse requirements are 2.744×10^6 pound-seconds (a 19.5 percent increase over the representative OLS impulse requirements). Impulse requirements are given in Table 2-2.

Table 2-2. Representative and Derivative OLS Impulse Requirements

RCS Function	Representative OLS (180 days)	Derivative OLS (180 days)
CMG Desaturation	153,000 lb-sec	92,000 lb-sec
Maneuvers	12,000	12,000
Orbit Maintenance	2,049,000	2,559,000
Emergency	82,000	81,000
Total	2,296,000	2,744,000

Orbit maintenance is the main contributor to total RCS impulse requirements (2.049×10^6 pound-seconds on the representative OLS and 2.559×10^6 pound-seconds on the derivative OLS). The greater sensitivity of the derivative OLS configuration to lunar gravitational perturbations explains the 510,000 pound-second orbit maintenance impulse difference between the two OLS configurations.

Total RCS cryogenic storage requirements are determined by 180-day RCS impulse and ECLSS requirements or 109-day RCS impulse and ECLSS requirements plus contingency provisions (whichever is larger). The cryogenic storage requirements for the two OLS configurations are summarized in Table 2-3.

Table 2-3. Representative and Derivative OLS
Cryogenic Storage Requirements (lb_m)

Cryogen	Representative	Derivative
LO_2	6823+	8042+
LN_2	3551** (*)	7349** (*)
LH_2	1645**	1913**
Subsatellite LN_2H_4	7811	7811

(*) Includes 455 lb_m LN_2 for subsatellite provisions
** 180 day requirements
+ 109 day requirements + contingencies

For the effect upon propellant resupply logistics see the discussion in Section 2.1.2 Consumables Resupply.

The sizing of the RCS cryogenic tank farm is significantly different between the two OLS configurations. Cryogenic fluid tankage is summarized in Table 2-4 for the two OLS configurations. The small 25.5 cubic feet tanks on the derivative OLS are identical to those on the MSS. The large 89.8 cubic feet derivative OLS tanks are based on zero excess of hydrogen

Table 2-4. Representative and Derivative OLS Cryogenic Fluid Tankage

Cryogen	Number of Tanks: Representative+	Number of Tanks: Derivative*
LO_2	2	3 small, 1 large
LH_2	8	6 large
LN_2	2	4 small, 1 large

*One additional small tank is added for oxygen in the forward, permanently docked cargo storage module CSM-1. Tanks: small = 25.5 ft^3, large = 89.8 ft^3.
+Assumes 64.4 ft^3 tanks using 10 percent ullage

Environmental Protection Subsystem (ENPS)

The micrometeoroid and radiation protection requirements for the representative and derivative OLS are identical. The total heat rejection requirement for the derivative OLS is 27.6 kw, instead of 26.6 kw on the representative OLS, in addition to the 1.1 kw load generated by the batteries in the power module which is transported to the manned module thermal control subsystem. Differences between the concepts employed by the two OLS configurations to meet the specified ENPS requirements are pointed out below.

Because the derivative OLS configuration has more exposed surface area requiring meteoroid protection, it was determined that a double bumper concept would be weight effective over a single bumper concept. A single bumper concept was chosen for the representative OLS. Minimum required bumper thicknesses, and consequently minimum bumper weights are different on the two OLS configurations. However, since considerations for ease of manufacturing, handling and maintenance determine the actual bumper thicknesses, the difference between meteoroid protection weights on the representative and derivative OLS configurations is primarily due to the increased area of the derivative OLS configuration and not the difference between the double bumper and single bumper concepts.

A summary of meteoroid protection data for the two OLS configurations is presented in Table 2-5. It should be noted that the representative OLS must employ a glass-epoxy bumper to protect the phased arrays of the ISS, while the derivative OLS has no such materials requirement because it uses parabolic dishes for external communications.

Table 2-5. Representative and Derivative OLS Meteoroid Protection Data

	AT (m2 - sec)	Concept	Material	t_1	t_2
Representative	2.14×10^{11}	S/B	Aluminum*	0.020 in.	--
Derivative	4.45×10^{11}	D/B	Aluminum	0.021 in.	0.00215 in.

*Except for glass epoxy on phased arrays

More surface area is available on the derivative OLS for location of radiators, but due to the interference between modules the effective radiator area is the same (2000 ft^2). The only significant difference (other than location of radiators) between representative and derivative OLS thermal protection concepts is the method of power module heat rejection. Because the derivative OLS batteries in the power module must be maintained at approximately 50F, the low temperature load must be transported with an active fluid loop to the other modules for rejection. The remainder of the power module heat load is rejected through 150F radiators, while 120F radiators are employed to reject all the heat of the representative OLS power module.

The solar storm shelter of the derivative OLS differs only in configuration from that of the representative OLS (both provide the required 16.6 gm/cm^2 of shielding). Because of the smaller diameter of the derivative OLS modules, the pressure shell forms one of the boundaries of the storm shelter, requiring additional high density shielding. It was a convenience to locate the complete back-up galley in the representative OLS storm shelter, whereas only a food reconstitution unit and provisions for a "borrowed microwave" oven exist in the derivative OLS storm shelter.

2.1.2 Mission Operations

This Section identifies and discusses those areas where differences in design of the two configurations have some impact upon operational procedures and logistics requirements.

Station Delivery to Lunar Orbit

Various methods for delivery of the representative OLS and derivative OLS to lunar orbit are presented in Sections 2.0 and 5.0 respectively of Volume V. Three different cislunar shuttles are considered, i.e., reusable nuclear shuttle (RNS), single chemical propulsion stage (CPS-1), and double chemical propulsion stage (CPS-2). Cislunar shuttle round trip flights and expended (all CLS propellant consumed on outbound leg) flights are discussed. The baseline mode of delivery to lunar orbit for both stations requires two RNS round trip flights.

The delivery of the derivative OLS in a partially assembled configuration on RNS flight no. 1 (as discussed in Section 5.0 of Volume V) causes bending moments to be induced into the docking ports and surrounding core module structure by side docked modules during CLS thrust maneuvers. This requires a structural beef-up of the effected docking ports totalling 1000 pounds per core module. The representative OLS, on the other hand, requires no docking port beef-up since no modules are side-docked during translunar flight.

The differences in the two station deliveries as they affect initial lunar orbit operations occur subsequent to arrival of RNS flight no. 2 in lunar orbit. Subsequent to RNS flight no. 1, in the case of both station deliveries, there are no operations in lunar orbit other than separation of the unmanned OLS payload from the RNS and activation of all required subsystems, including the integrated G&C and RCS subsystems, for attitude control and orbit maintenance. Subsequent to RNS flight no. 2, initial lunar orbital operations differ significantly between the two OLS stations, but only in detail. The representative OLS payload on RNS-2 consists of the experiment module, an 8-man crew and a fully fueled tug. The tug operations consist of transporting the crew and the experiment module to the OLS core module, and performing two docking operations; one to dock the experiment module and one to dock itself to the core module. The derivative OLS payload on RNS-2 consists of control center module CCM-1, cryogenic storage module CSM-2, an 8-man crew, and a fully fueled tug. The tug operations in this case involve the docking of CCM-1 and CSM-2 to the appropriate core module docking ports, the redocking of the experiment module from a side port to a +Z axis docking port (along lunar nadir), and the connecting of a flex port between the galley module GM and the control center module CCM-1. Similar differences in tug operations occur in earth orbit during partial assembly of the two stations preparatory to the cislunar shuttle flights.

In conclusion the initial station delivery and buildup operations for the derivative OLS are more complex in terms of numbers of modules to be docked and the additional requirement for flex port installations. A more detailed study is required to fully evaluate the magnitude of the differences in operational complexity.

Consumables Resupply

Logistics resupply to both of the OLS configurations is provided in the same manner, i.e., cryogenics are delivered in the propellant module, and the cargo is delivered in the dual-support cargo module. There is no difference in the 109-day cargo resupply requirements, however, the 109-day cryogenic resupply requirements are significantly different due to differences in N_2/O_2 leakage rates (see Section 2.1.1, EC/LSS) and differences in RCS propellants for station attitude hold and orbital maintenance (see Section 2.1.1, RCS)

Table 2-6 presents a comparison between the 109-day cryogenics requpply of the two OLS configurations.

Table 2-6. 109-Day Cryogenics Resupply

		Representative	Derivative
LO_2	lb	3126	4345
LH_2	lb	996	1158
LN_2	lb	2000	4300
Total	lb	6122	9803

Although the cryogenic resupply requirements for the derivative OLS are approximately 60% higher than for the representative OLS, the impact upon sizing of the propellant module is small. The propellant module defined in Section 8.0 of Volume II is sized for the representative configuration at 77000 pounds total cryogenics, including tug propellants. A propellant module sized for the derivative configuration would have a total capacity of approximately 80700 pounds, or an increase of approximately 5 percent. This 3700 pound increase results in a 3 percent increase in cislunar shuttle payload each 109 days.

Docking Operations

The docking operations of the derivative OLS configuration, subsequent to assembly of the operational station in lunar orbit, are almost identical with the operations described in Sections 8.0 and 9.0 of Volume II for the representative OLS. The propellant module will dock to the cryogenic storage module CSM-2 to replenish the derivative OLS cryogenic tanks; whereas in the case of the representative OLS, the propellant module will dock directly to a core module docking port. No significant difference is anticipated in operations associated with the docking of tugs, dual-support cargo modules, and experiment subsatellites to the two OLS configurations. A design driver, however, is imposed upon the lunar lander tugs by the derivative OLS configuration in that the tug must have articulating landing gear for partial retraction. The partial retraction is necessary to avoid contact between the docked tug landing gear foot pads and the cylindrical sides of functional modules which are docked to the two core modules (see Drawing 2282-29, Section 7.1 of Volume V). The representative configuration permits the tug landing gear to be fully extended in the docked configuration, primarily due to the larger diameter core module (see Drawing 2282-27, Section 2.1 of Volume V).

2.1.3 Safety, Escape and Rescue

Both OLS configurations have been developed with safety as a paramount consideration in the design and configuration arrangement selection. There has been no compromise in either OLS configuration where safety is concerned. Each configuration has dual ingress/egress routes to all habitable areas, an IVA/EVA airlock, dual pressurized volumes, a solar radiation storm shelter, micro-meteoroid protection, isolated location of potentially explosive containers, etc. Therefore, no difference exists between the two stations in regards to safety.

Both OLS configurations have been designed to the same crew rescue and safety support requirements in terms of contingency consumables and crew accommodations for personnel rescued from other lunar program elements; and in terms of back-up command and control, and communications relay support to other elements. The capabilities of the two stations for escape and rescue of OLS personnel are also identical. Rescue is provided by a tug normally docked to the station, with capability to rescue the entire crew to a safe earth orbit (see Section 5.0 of Volume II for safety and rescue requirements and capabilities).

2.2 SCHEDULE COMPARISON

Two separate configurations have been considered during the Orbiting Lunar Station (OLS) Study. A comparison of the two configurations shows that the representative OLS configuration is made up of three modules, i.e., a core module with a diameter of 27 feet and length of 60.8 feet; an experiment module with a 15-foot diameter and a length of 22 feet; and a power module which is 35.5 feet in length and 7 feet in diameter. The derivative OLS modular configuration is made up of eleven modules which consist of: two core modules, one power module, two crew modules, one galley module, two control modules, one experiment module, and two cryo storage modules. Both configurations have an eight-man crew with a mission duration of ten years. The on-orbit assembly of representative OLS modules has an overall length of 130 feet (solar arrays deployed) with a total gross weight of 157,625 pounds; while the on-orbit assembly of derivative OLS modules has an overall length of 161.5 feet and a total gross weight of 223,004 pounds.

The same basic program ground rules were applied to the study of both the OLS configurations, and are reflected in the preparation of the documentation that comprise the Cost and Schedule Projection Report. These program assumptions include:

1. Launch is assumed to be June 1, 1983
2. In Operational Condition (IOC) date, December 1, 1983
3. An earth orbital Modular Space Station is a precursor to the OLS.

An evaluation and comparative analysis of the cost and schedule projection documentation for the representative OLS and the derivative OLS indicate significant variations in program schedules and plans requirements. These variations are depicted in the comparison charts and graphs that follow.

The Work Breakdown Structure Comparison (Table 2-7) is structured to show major program elements (level 4) for both the representative OLS and derivative OLS. The program elements reflect the principal categories of hardware, services, and related work tasks involved in the development and production of the OLS. The only difference is the chart indicates eight additional modules of the derivative configuration.

Table 2-7. Comparison of Work Breakdown Structures

Major Tasks - Level 4 for Representative OLS	Major Tasks - Level 4 for Derivative OLS
Core Module Flight Hardware	Core Modules - 1A
Experiment Module Flight Hardware	Core Modules - 1B
Power Module Flight Hardware	Power Module
Test Hardware	Crew Module #1
Operations Support	Galley Module
Facilities	Crew Module #2
Ground Support Equipment	Control Module #1
Training Equipment	Control Module #2
Systems Support	Experiment Module
Program Management	Cryo Storage Module #1
Spares	Cryo Storage Module #2
	Test Hardware
	Operations Support
	Facilities
	Ground Support Equipment
	Training Equipment
	System Support
	Program Management
	Spares

Table 2-8 summarizes the test article requirements for both the representative OLS and derivative OLS. The mockup and structural test article requirements for the derivative OLS are greater than required for the representative OLS. However, the ground test requirements for the representative configuration are more extensive because it was assumed that the acoustic, dynamic and thermal tests of the derivative OLS will be accomplished on the MSS and would not be required again for the adapted OLS modules. Separate test articles are required to accomplish these tests on the representative OLS.

The Program Development Schedules Comparison Chart (Table 2-9) summarizes the key milestones and dates for the representative OLS and derivative OLS programs. An analysis of the data on this chart shows that the lengths of the two programs are similar, with the derivative OLS program being two months longer than the representative OLS program. Considerable storage periods are required for the flight modules shown on the derivative OLS schedules while no storage is required for the representative OLS program. Launch operations for the derivative OLS are longer to reflect incremental earth orbit shuttle flights.

The Manufacturing Time Spans for Flight Vehicles Comparison (Table 2-10) summarizes the required flow time in months for the flight hardware for each of the OLS configurations. The time periods shown are from the start of fabrication through delivery. The manufacturing schedule for the derivative OLS is based on a module fabrication start rate of one every two months.

2.3 COST COMPARISON

A comparison of total program cost for the two OLS configurations, representative and derivative, show the derivative concept is the less costly candidate.

Compared to the representative OLS configuration, the non-recurring design and development (DDT&E) cost is considerably lower as most of the modules for the derivative OLS are derived from earth orbital MSS hardware while the representative OLS configuration is unique and requires more design and development, major test hardware and related testing. Derivative OLS flight hardware dry weight is considerably higher due to the number of modules required and the derived recurring production cost is therefore more costly. Operational costs are slightly higher on the derivative OLS configuration due to the higher flight hardware weight.

The following tables illustrate in both annual and cumulative funding the comparisons described abcve.

The OLS Annual Funding Comparison Schedule (Figure 2-1) summarizes the annual funding requirements for the representative OLS and derivative OLS programs. Funding requirements are broken down into DDT&E, Production and Operations costs. Maximum funding for the representative OLS is in GFY 1980 and 1981 while maximum funding occurs in 1981 and 1982 for the derivative OLS reflecting the impact of utilizing MSS technology.

Table 2-8. Comparison of Test Articles

Representative OLS	Derivative OLS	Remarks
	Mockups	
Core module (soft) Experiments module (soft)	Galley module Experiments module Control module #1 Cryo storage module #2	Full size - soft mockups
	Structural Tests	
Core module Experiments module	Experiments module Control module #1 Core module 1B Cryo storage module #2	Structural test articles become part of interface test article/mission support vehicle upon completion of tests
	Other Ground Tests	
Acoustic test article Dynamic test article Thermal test article	None	1. Acoustic, dynamic, and thermal tests for the derivative OLS accomplished on MSS 2. Representative OLS acoustic test article becomes part of dynamic test article
	Interface Tests	
Compatibility mockup Mission support vehicle	Interface test article	1. Derivative OLS structural test articles combined with MSS modules for interface tests and mission support 2. Mission support vehicle and interface test article use structural test article 3. MSS power module used for mission support 4. Representative OLS mission support vehicle uses subsystems from compatibility mockup and thermal test article

Table 2-9. Comparison of Program Development Schedules

Key Milestones and Dates	Representative OLS	Derivative OLS
Start Phase B (Definition)	4-1-75	2-1-75
Complete Phase B	3-31-76	2-1-76
Start Phase C (Design)	10-1-76	8-1-76
System Dsn. Review (SDR)	1-1-77	11-1-77
Prelim. Dsn. Review (PDR)	7-1-77	5-1-77
Complete Phase C	10-1-77	8-1-77
Start Phase D (Devel./Opns)	10-1-77	8-1-77
Critical Design Review (CDR)	10-1-78	8-1-78
Mockups Available	10-1-78	8-1-78
Start Acoustic Test	4-1-80	*
Start Compatibility Tests	1-1-81	*
Start Thermal Test	1-1-81	*
Start Structural Test	1-1-81	5-1-79
Complete Grd. Devel. Tests	1-1-82	12-1-80
Product Config. Audit (PCA)	1-1-83	10-1-82
Del. Flt. Articles to KSC	2-1-83	11-1-82
Flt. Readiness Review (FRR)	5-1-83	2-1-83**
1st Translunar Flight	6-1-83	6-1-83
IOC	12-1-83	12-1-83
Storage Required for Opns. Veh.	No	Yes

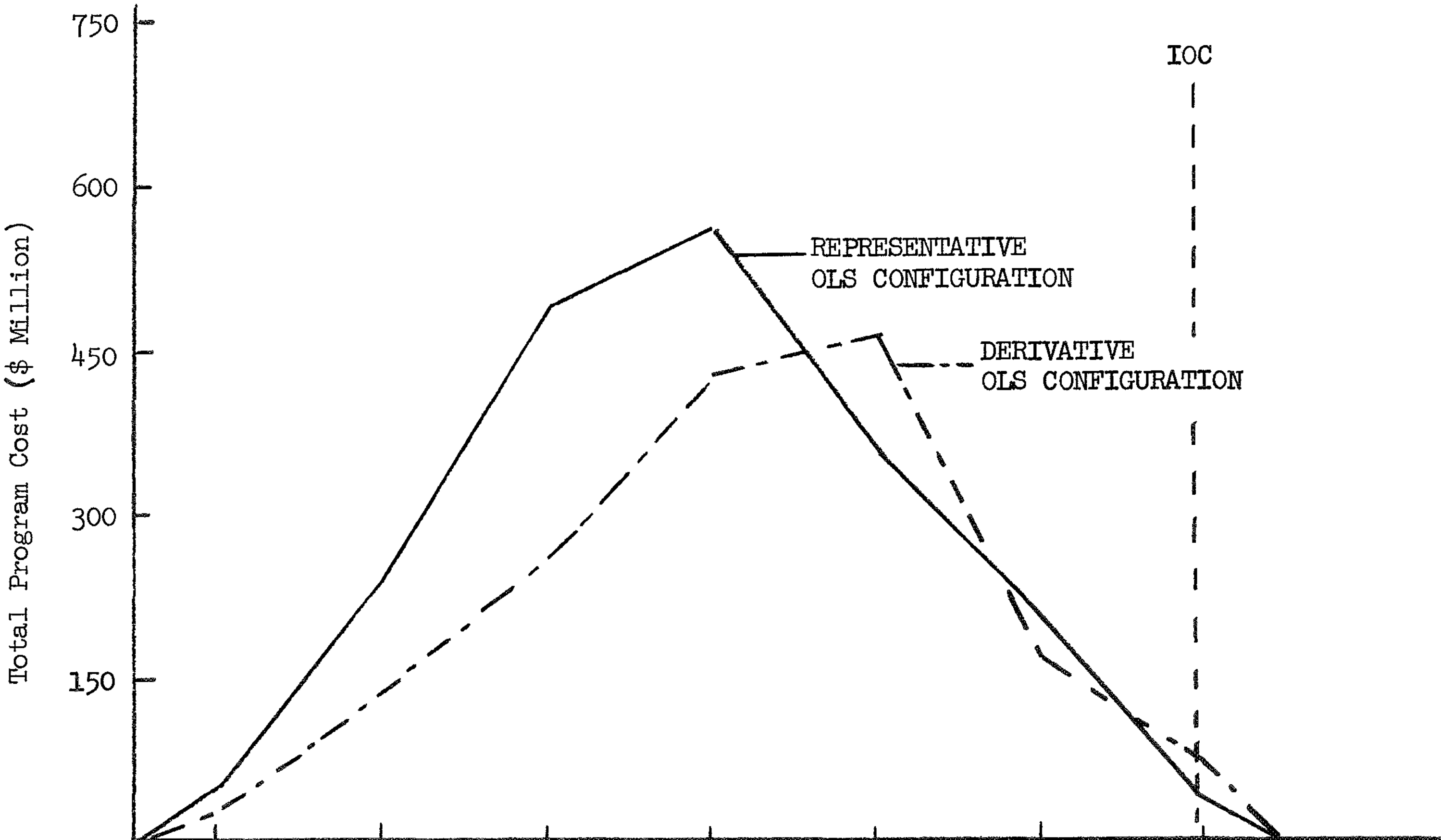
* Acoustic, thermal, compatibility tests of MSS are assumed to be adequate; no additional tests of this type are proposed for the adapted OLS modules.
**Corresponds to earth orbit delivery of first derivative OLS module by the earth orbit shuttle.

Table 2-10. Comparison of Manufacturing Time Spans of Flight Hardware

Representative OLS		Derivative OLS	
Module	*Time Span Months	Module	**Time Span *Months
Core Module	37	Core Module 1A	21
Experiments Module	23	Core Module 1B	21
Power Module	17	Crew Module #1	16
		Galley Module	16
		Crew Module #3	16
		Control Module #1	16
		Control Module #2	16
		Experiments Module	16
		Cryo Storage Module #1	16
		Cryo Storage Module #2	16
		Power Module	16

Notes: * Time span is from start of fabrication through delivery.
**Module fabrication starts at 2 month intervals.

Figure 2-1. OLS Annual GFY Funding Comparison Schedule

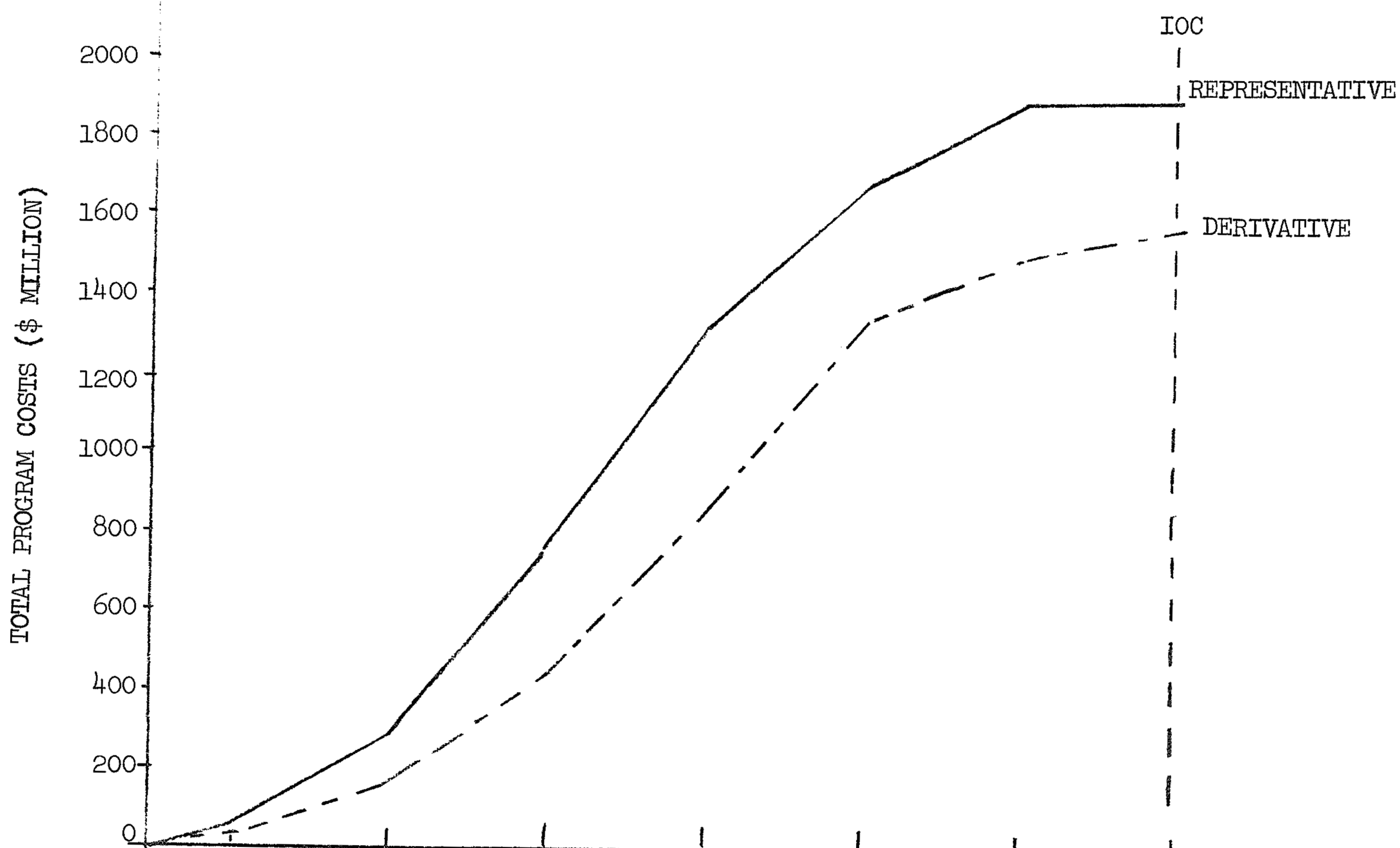


GFY	1978		1979		1980		1981		1982		1983		1984		Totals	
	Rep.	Der.	Rep.	Der.	Rep.	Der.	Rep.	Der.	Rep.	Der.	Rep.	Der.	Rep.	Der.	Rep.	Der.
DDT&E	45.2	29.2	235.9	138.	481.7	256.1	475.9	262.0	135.7	124.1	2.2	8.5			1376.6	817.9
Production					3.9	7.8	61.9	153.9	149.1	279.6	132.9	86.2			347.8	527.5
Operation							19.2	15.0	74.8	64.9	74.4	82.4	33.9	71.5	202.3	233.8
Total	45.2	29.2	235.9	138.	485.6	263.9	557.0	430.9	359.6	468.6	209.5	177.1	33.9	71.5	1926.7	1579.2

The OLS Cumulative GFY Funding Comparison Schedule (Figure 2-2) shows the cumulative funding requirements for the representative OLS and derivative OLS programs. Funding requirements are broken down in DDT&E, Production and Operations costs on a GFY basis commencing with the GFY 1978 through GFY 1984.

The Cost Distribution Comparison (Tables 2-11, 2-12, and 2-13) show non-recurring (DD&T) and recurring (Production) and (Operation) costs requirements for each of the major program elements for both the representative OLS and derivative OLS programs. Percentages of the total cost are shown for each of the program cost elements.

Figure 2-2. OLS Cumulative GFY Funding Comparison Schedule



GFY	1978		1979		1980		1981		1982		1983		1984	
	REP	DER	REP	DER	REP	DER	REP	DER	REP	DER	REP	DER	REP	DER
DDT&E	45.2	29.2	281.1	167.2	762.8	423.3	1238.7	685.3	1374.4	809.4	1376.6	817.9	1376.6	817.9
Production					3.9	7.8	65.8	161.7	214.9	441.3	347.8	527.5	347.8	527.5
Operations							19.2	15.0	94.0	79.9	168.4	162.3	202.3	233.8
Total	45.2	29.2	281.1	167.2	766.7	431.1	1323.7	862.0	1683.3	1330.6	1892.7	1507.7	1926.7	1579.2

Table 2-11. Cost Distribution Comparisons
Non-Recurring (DDT&E)

Cost Element	Representative OLS Cost (millions)	Representative OLS % of Total	Derivative OLS Cost (millions)	Derivative OLS % of Total
Design & Development	557.7	40.4	484.9	59.2
Test Hardware	438.4	31.8	107.1	13.0
Ground Support Equipment	154.4	11.2	91.7	11.2
Training Equipment	24.9	1.8	14.8	1.8
Facilities	86.7	6.3	51.5	6.3
Systems Support (Sys Eng)	66.7	4.8	39.6	4.8
Program Management	47.8	3.7	28.3	3.7
Total	1,376.6	100.0%	817.9	100.0%

Table 2-12. Cost Distribution Comparisons
Recurring (Production)

Cost Element	REPRESENTATIVE OLS		DERIVATIVE OLS	
	Cost (millions)	% of Total	Cost (millions)	% of Total
Flight Articles	299.9	86.1	455.0	86.3
Sustaining GSE	5.8	1.7	8.6	1.6
Systems Support (Sys. Eng.)	9.3	2.7	14.1	2.7
Spares (Initial Flt)	11.0	3.2	16.8	3.2
Program Management	6.9	2.0	10.4	1.9
Pre-mission Operations	14.9	4.3	22.6	4.3
Total	347.8	100.0%	527.5	100.0%

Table 2-13. Cost Distribution Comparisons - Recurring (Operations)

Cost Element	Representative OLS		Derivative OLS	
	Cost (Millions)	Percent of Total	Cost (Millions)	Percent of Total
Mission operation support	22.3	11.0	33.8	14.4
Spares (10 years operational)	180.0	89.0	200.0	85.6
Totals	202.3	100.0	233.8	100.0

3.0 REPRESENTATIVE OLS COST AND SCHEDULE DATA

This section presents cost and schedule data for the representative OLS. Identification of the hardware requirements of the OLS configuration defined in Volume V are presented in a hardware tree. Development test requirements are identified including required major test articles. Total hardware requirements are identified in a hardware utilization list. Based upon an IOC date of 1983, manufacturing schedules are developed for the flight hardware.

All facets of the program including design, development, fabrication, and test are integrated into a program development schedule. Figure 3-1 presents a summary of that schedule. Major program phasing depicted on the schedule includes a 12-month Phase B definition study to commence on April 1, 1975, followed by a 6-month customer evaluation and review period. A 12-month Phase C design study is scheduled to start October 1, 1976 and upon the completion of Phase C, the program will proceed directly to Phase D, development/operations. One major planning assumption used in the preparation of the Preliminary Program Development Schedule is that launch will take place June 1, 1983 followed by an in operational condition (IOC) date six months later or December 1, 1983. The timing and duration of the phases reflect this program ground rule.

The test program to support the representative OLS development is shown to start April 1, 1980 and complete January 1, 1982. Test articles required for development testing along with the manufacturing time spans and testing spans are shown on the summary schedule. Time spans for the various test articles vary in length depending on the amount of structure to be fabricated or systems to be installed. As shown on the schedule, considerable savings in manufacture time and monetary cost is realized by the re-utilization of test articles for additional testing.

A Work Breakdown Structure which was developed jointly by NASA/MSC and NR personnel during the study is presented. All cost data is referenced to the WBS.

Program cost data include methodology, summaries with schedules, detail cost, and technical characteristics. The cost data is presented in accordance with the Data Requirements Description for DRL line item 1. Included are:

1. Data Form A. Total program cost estimate data by WBS item
2. Data Form C. Representative OLS technical characteristics data
3. Data Form D. Total program funding schedules

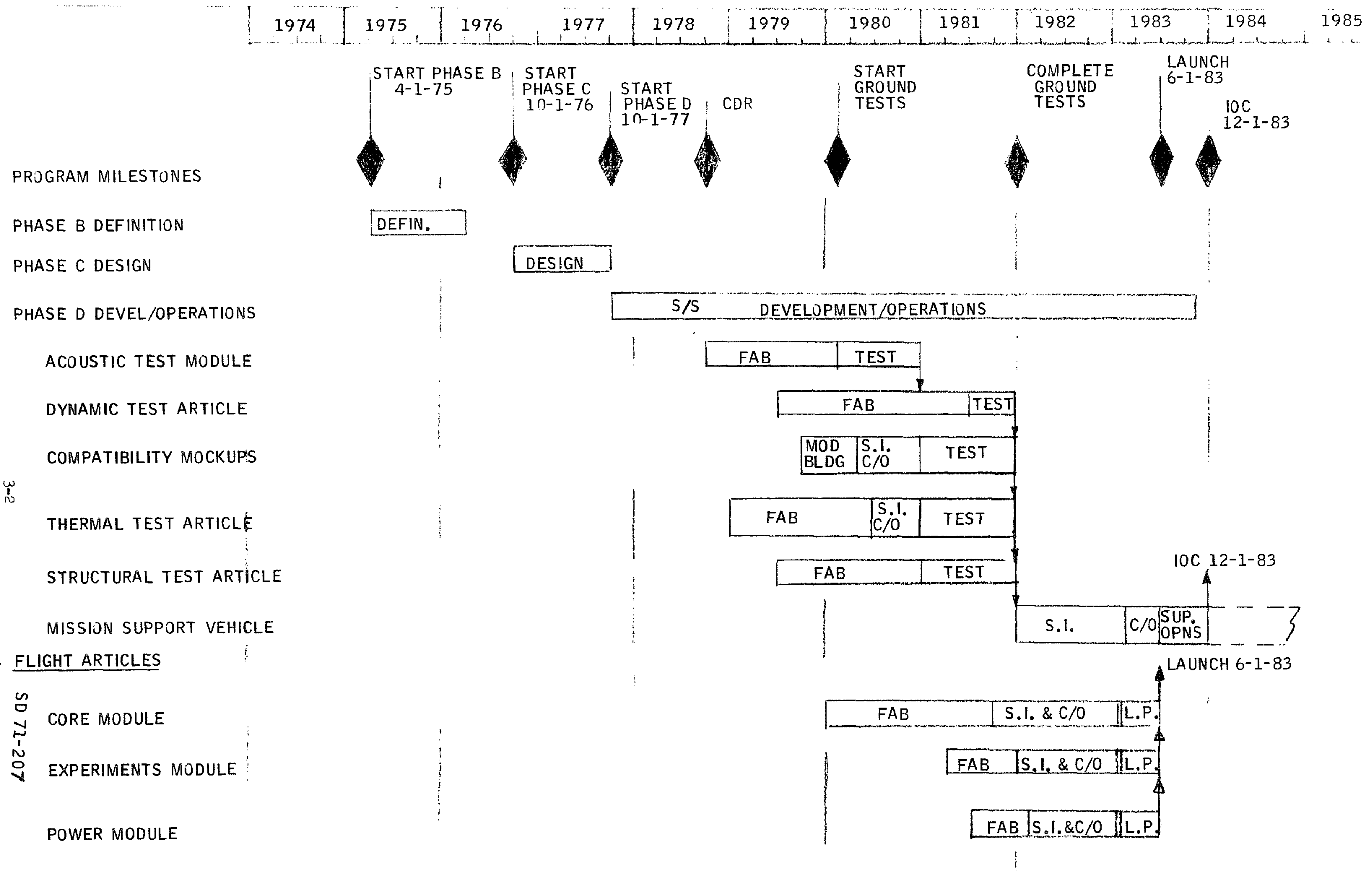


Figure 3-1. Representative Orbiting Lunar Station - Preliminary Program Development Summary Schedule

3.1 HARDWARE TREE

Based upon the representative OLS configuration defined in Volume V, a preliminary hardware tree, Figure 3-2, was developed which identifies OLS modules (systems), subsystems, and major subassemblies. The hardware tree is a key tool in the identification of development requirements, major test articles, and the program development schedule. The Hardware Utilization List (HUL) is an update of the Tree and incorporates all units of the Tree that are fabricated. The Work Breakdown Structure (WBS) groups the items of the Tree into appropriate pricing subdivisions.

3.2 DEVELOPMENT TEST REQUIREMENTS

This section delineates a test planning concept or approach for the representative OLS which is applicable for long-duration space subsystems.

3.2.1 Test Philosophy

The test approach is designed to provide assurance that the OLS can be successfully launched into earth/lunar orbit and be capable of safely remaining in lunar orbit for the duration of its ten-year operational life in order to successfully achieve all of its mission objectives. To provide this assurance, the test program begins in Phase B during preliminary design and continues through Phase C design, and Phase D fabrication and assembly into the mission operations time period.

The basic consideration during the Phase B time period will be to establish the development issues requiring resolution and to integrate them into a development/test structure that will accommodate the unique aspects of the representative OLS. Figure 3-3 presents a Development Requirements Analysis (DRA) approach which will provide a logical buildup of test article requirements beginning with the concept selection and trade studies. In the Phase B study the emphasis will be placed on the subsystem and its major subassemblies. The DRA format can be readily extended to accommodate Phase C levels.

Launch confidence/assurance will be obtained through use of classical test approaches in an integrated program designed to assure satisfaction of all development and design requirements. This integrated test program concept is illustrated in Figure 3-4.

Major features of such a test philosophy are:

1. Develop an integrated launch confidence assurance program which assures that each development, qualification, and acceptance test contributes to the total program with the proper emphasis at the proper time.

2. Utilize a central, computerized data bank to provide standardized source and historical data for all test parameters and functions from development testing through on-orbit operations.

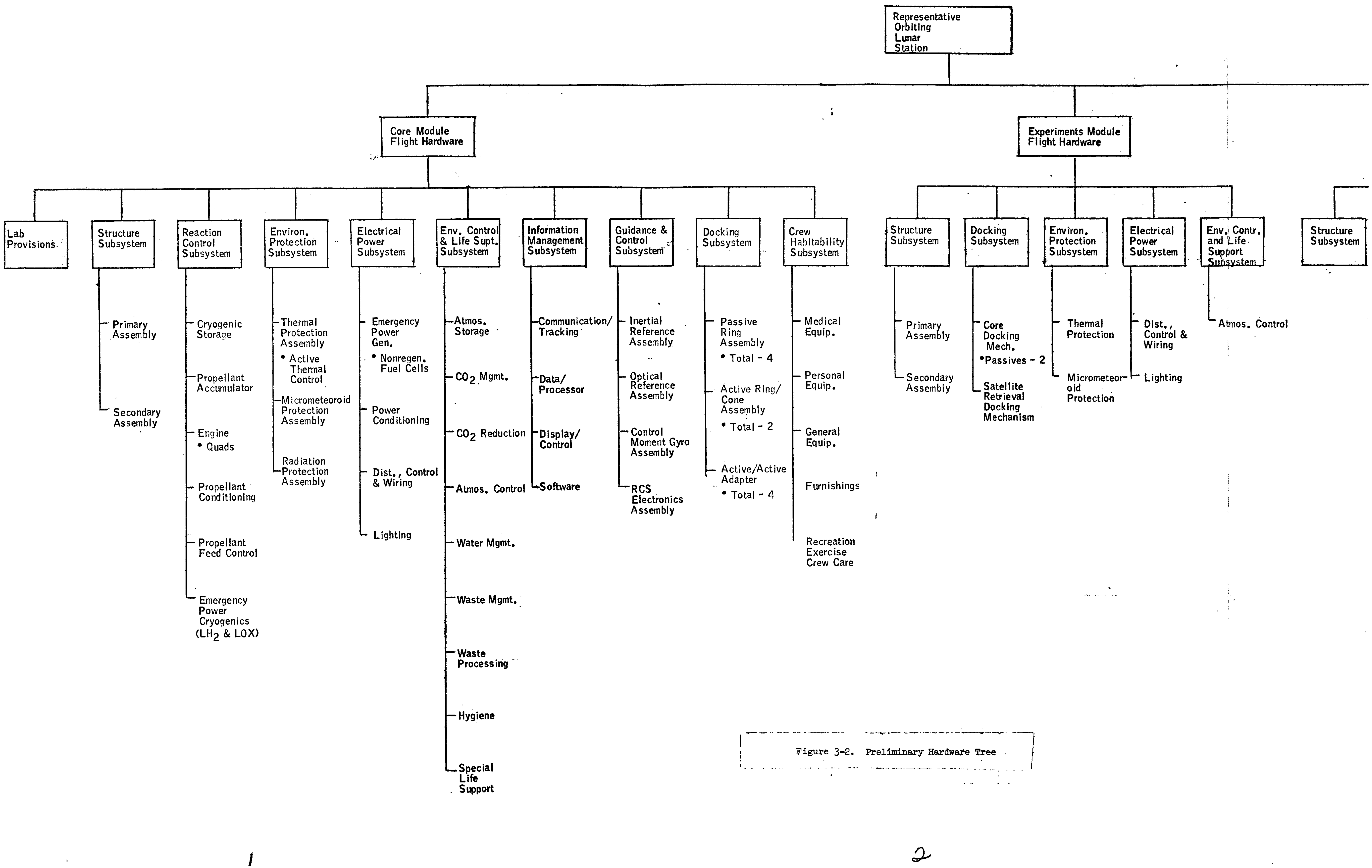
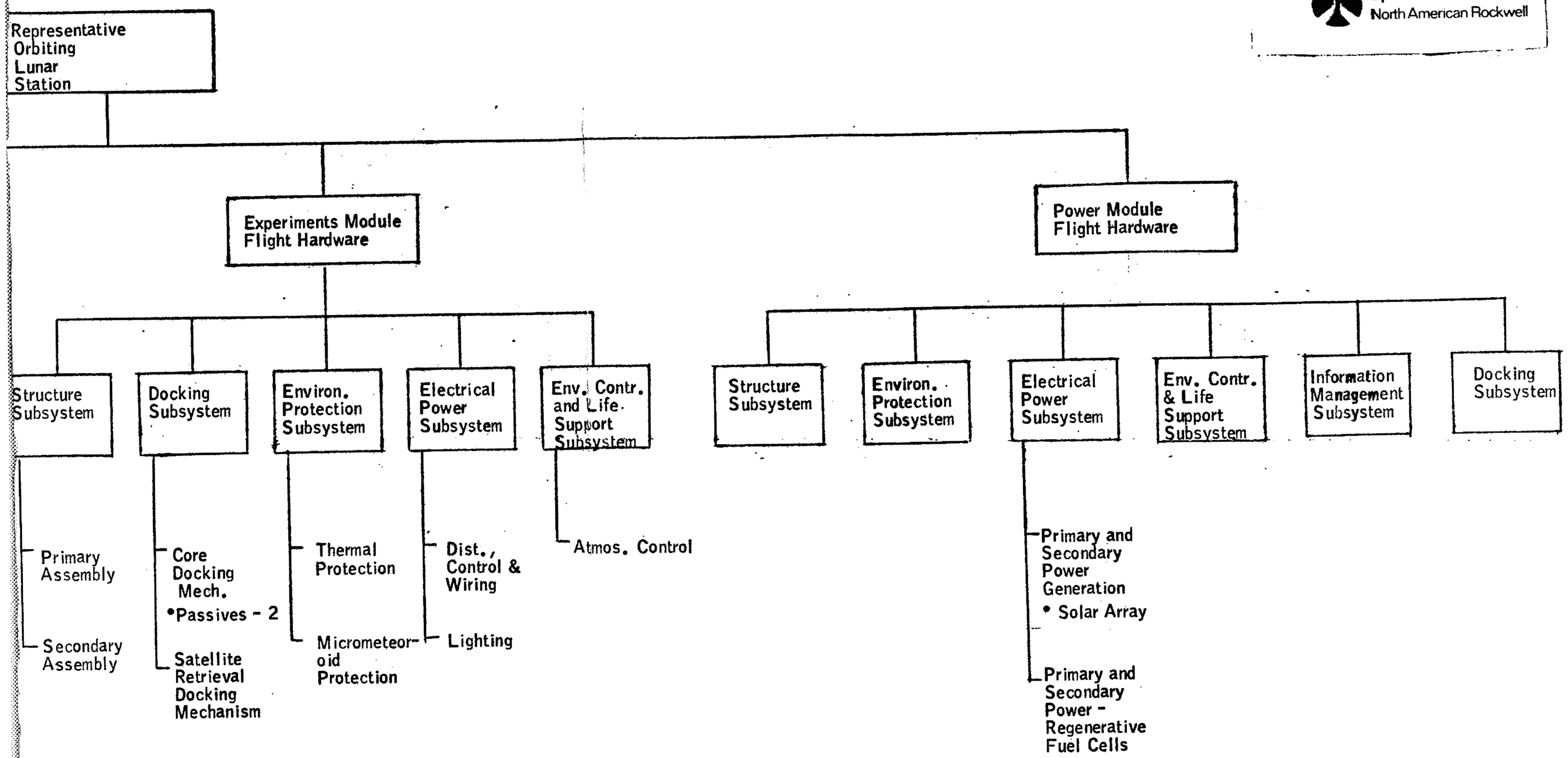


Figure 3-2. Preliminary Hardware Tree



minary Hardware Tree

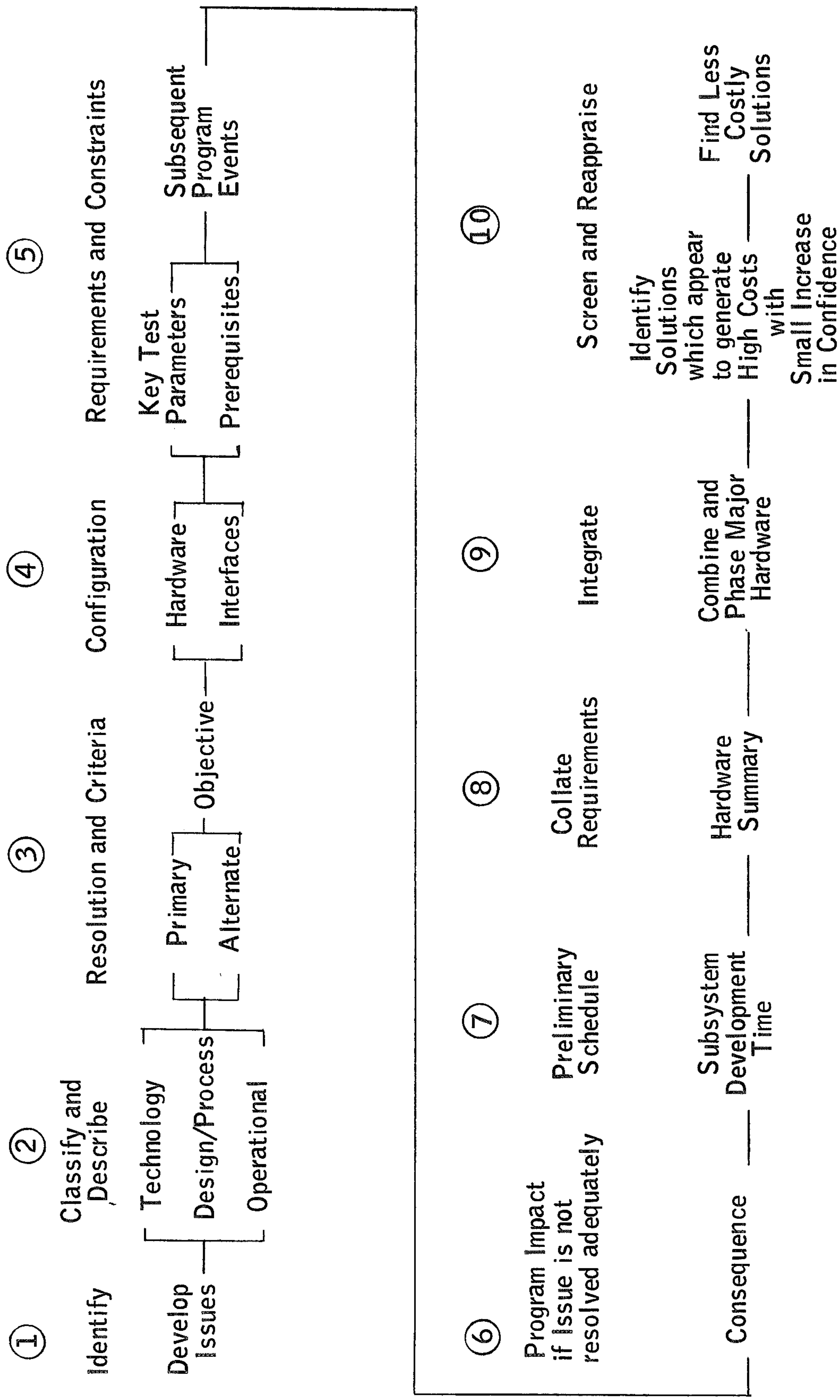


Figure 3-3. Development Requirements Analysis Process

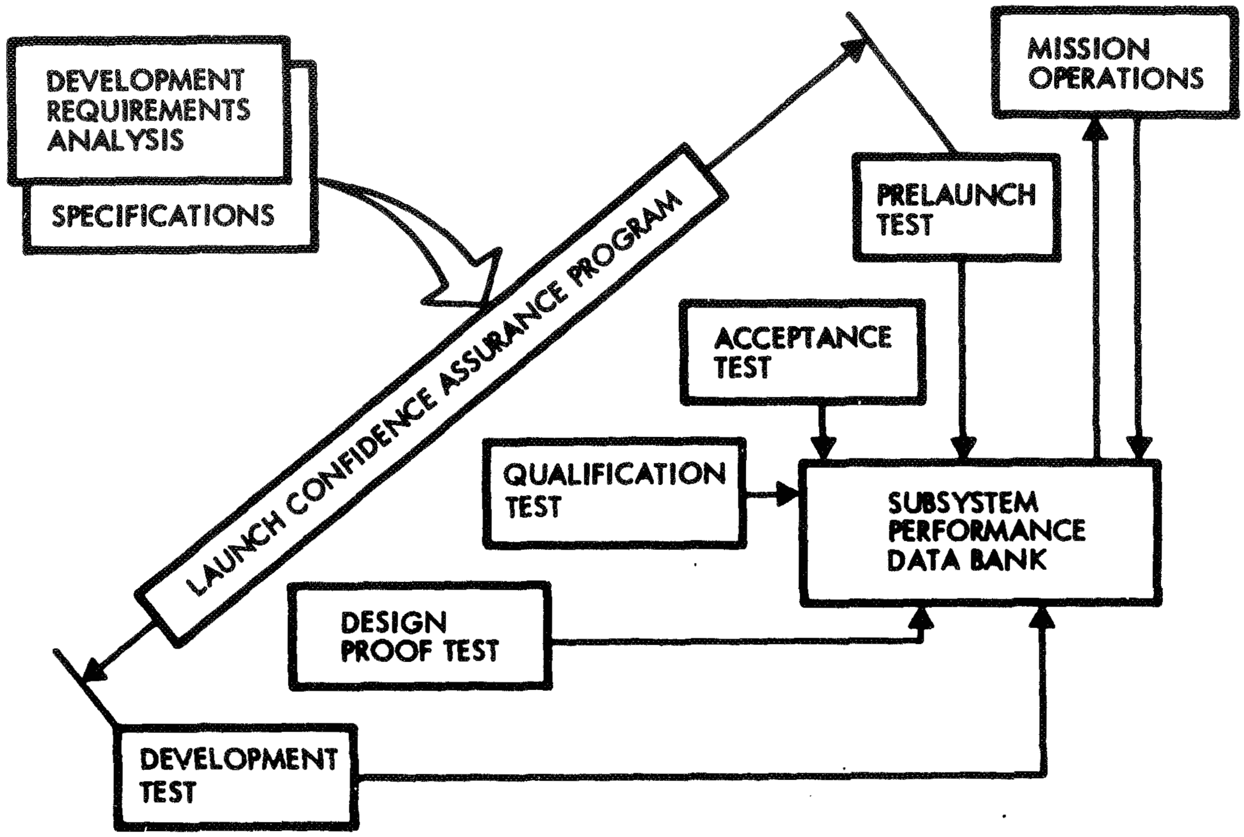


Figure 3-4. Integrated Test Program Concept

3. Place early and strong emphasis on the integration and utilization of the onboard checkout capability of the information subsystem.

4. Place early and strong emphasis on the physical and functional integration of subsystems.

5. Establish design margins that will permit acceptance test conditions exceeding mission requirements without degradation of the item under test.

6. Development test requirements from a methodical analysis of subsystem concepts and preliminary designs.

7. Evaluate each test requirement for the optimum cost/ confidence resolution.

Application of these principles to test planning during Phases B/C will result in a cost-effective test program capable of providing the launch confidence/ assurance required for manned space vehicle programs.

3.2.2 Test Requirements

There are three basic classifications of test requirements: (1) Development Tests, (2) Qualification Tests, and (3) Acceptance Tests. The requirements of each are developed in subsequent paragraphs. Throughout the discussion specific hardware terminology is used. The following list of definitions is presented to clarify their meaning.

1. Breadboards. Built with off-the-shelf type hardware. Testing is performed in ambient environments. The purpose of these tests is to determine the probable success of design concepts at an early stage in the program.

2. Prototype Hardware. Built to OLS specifications but is not necessarily fabricated with the same tooling nor to the same manufacturing controls as the flight hardware. Tests are conducted to acquire performance data at selected environments and to obtain data that identify sensitive parameters and their value in subsequent checkouts of the subsystems.

3. Soft Mockup. Constructed of wood with interior furnishings and subsystems simulated.

4. Compatibility Mockup (CMU). Provides for installation of major subsystem components, their interconnections with other subsystems, and the onboard checkout equipment. It is used to satisfy integrated test requirements during the development test phase. Installed subsystems will be prototype and flight-type hardware, depending upon scheduled availability. It will also include the experiment module.

5. Structural Test Vehicle. Consists of the complete primary structure for the OLS but very little, if any secondary structure. Insulation, thermal finishes, fairings, and subsystems are not included. The loading techniques used in the static structural test program and the design margins must be established to preserve the operational capability to the greatest extent possible. The static test structure will be utilized to make up the mission support vehicle upon completion of the structural program and the addition of all secondary structure.

6. Mission Support Vehicle. Completely configured OLS (excluding solar arrays) including an experiment module. Maintained in operational status during the life cycle of the orbiting station. It will serve as a prelaunch fit and functional (including software) checkout station for spares, modification kits, inflight replaceable units (IFRU's), and experiments having a dynamic interface with the orbiting station. The mission support vehicle will

6. Mission Support Vehicle. (continued)
also serve as a training device for replacement crew members and as a ground station for development of new procedures, assessment of malfunctions, and verification of long-life criteria.

7. Acoustic Test Article. Consists of one deck, an upper torus, a power boom, and a boost shroud. All subsystems over 50 pounds which are normally mounted in the upper-torus area, upper equipment bay, and power boom will be simulated in terms of mass and center of gravity. Upon completion of acoustic tests, this test article will be mated to the other three decks and lower torus which make up the dynamic test vehicle.

8. Dynamic Test Vehicle. Consists of almost all of the primary structure and secondary structure. Upon completion of acoustic tests, the acoustic test article is mated to three new decks and upper torus to form the dynamic test vehicle. All subsystems over 50 pounds will be simulated in terms of mass and center of gravity.

9. Thermal-Integration Test Article. Consists of two decks, an upper and lower torus, an upper tunnel, upper skirt and cone, lower tunnel, lower skirt, a lower structural closeout. There will be no pressure bulkhead, but the six tension ties will be installed. There will be no cryogenic storage in the upper equipment bay. The upper torus area will have no equipment installed except the pumpdown components. ECLSS assemblies will be installed in the lower equipment bay. The reverse-osmosis unit will be installed. The equipment airlock, window, and intervolume airlock are required for resolution of some detailed test objectives, as are one set of radiators and environmental shields.

Development Test Requirements

The long-life, high-reliability requirements of the OLS coupled with the limited production quantities, dictate the selection of proven material, compnents, and techniques wherever possible. Therefore, the primary development testing requirements will be to integrate and optimize the equipment and software. Some development testing of new concepts, techniques and materials will also be required. The test effort will be conducted primarily with breadboard and prototype hardware. This activity is where appreciable cost savings may be realized through application of rigorous test justification and hardware conservation principles. Verification of compliance with performance requirements will be satisfied by analysis and/or development tests. In those cases requiring resolution by test, the procedure described in the following paragraphs will apply.

The determination and verification of checkout and operational procedures will be a requirement of the subsystem development program. During development testing, the parameters which are most indicative of the performance capability of the subsystem and/or component being tested will be established. These data will be incorporated into a data bank for use in defining checkout procedures and resolving data anomalies during subsequent higher level assembly tests.

Maintenance concepts and procedures will be developed during the subsystem development program and verified initially on the compatibility mockup. Procedures developed subsequent to the station launch will be verified on the Mission Support Vehicle (MSV). The MSV configuration will be maintained both physically and functionally; therefore, maintenance concepts and procedures, as appropriate with one g, can be verified.

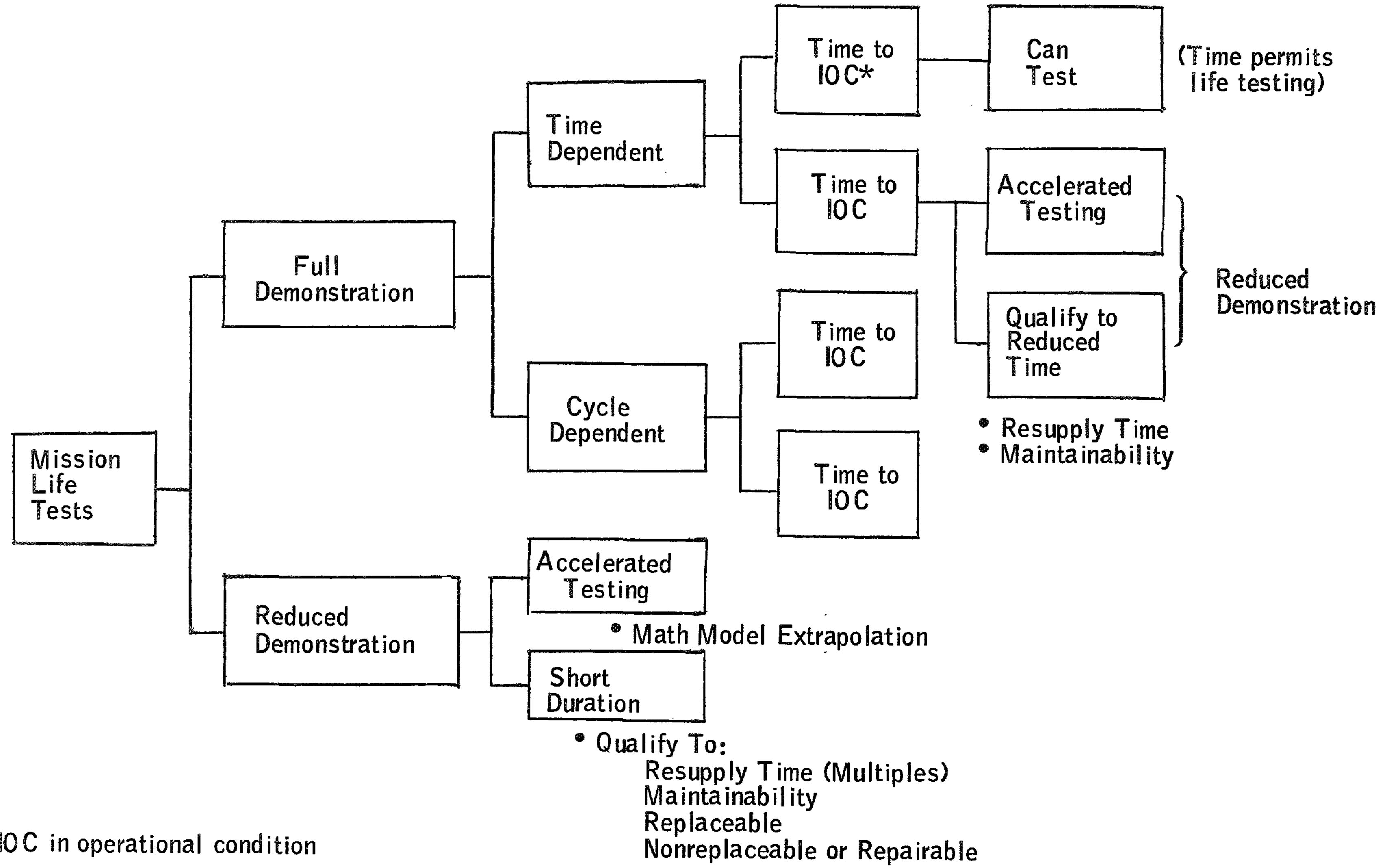
Structural testing will verify a satisfactory design margin for operational limits. Destructive testing of major structural test articles will be avoided to permit reuse of major structural test articles in subsequent test operations. Tests performed on major structural test articles will be performed at less than the conservative design factor (e.g., 1.5 times on primary structure).

All primary structures and structural interfaces between program elements will be statically and dynamically verified by test and/or analysis. Adequate tooling and/or fit-check fixtures will be used to demonstrate physical mating of all program elements before initial launch to assure OLS compatibility. These same tools and/or fixtures will be used to verify the compatibility of subsequently launched elements with existing elements.

The compatibility mockup will be used to verify the initial onboard checkout capability and software. Capabilities and hardware subsequent to initial launch will be verified on the MSV. If the onboard checkout system is to be used as a checkout tool, the subsystem software must be verified before its operational use. The CMU or MSV will be a part of this function.

Interface tests at the subsystem level will be conducted to determine interactions and to verify compatibility with other subsystems including the onboard checkout portion of the Information Subsystem (ISS). Tests will be conducted for both alternate and redundant modes at operational and limit levels. Interfaces between components and subassenblies within a subsystem will be verified in individual development tests and qualification tests.

Mission life test will be based upon resupply considerations or schedule maintenance periods and multiples thereof, rather than on the total life expectancy of ten years. Assurance of component long life and reliable operation will be assisted by establishment of design requirements that consider off-the-shelf component history, performance derating, and MSS operational data. It is impractical to use a classic life test (two times mission duration plus one ground cycle) for the OLS which has a planned operational life of ten years. Therefore, life testing requirements will be identified for each subsystem as it is defined, based upon the logic diagram of Figure 3-5. Failure-prone components and assemblies will be analyzed for mechanics of failure and tested as shown in Table 3-1.



*IOC in operational condition

Figure 3-5. Mission Life Tests

Table 3-1. Long-Life Testing

Mechanics of Failure	Characteristic	Test Mode
Wearout and degradation (i.e., bearings, seals, switches)	Change of state with time	Time compression techniques Extrapolation of historical data Tests at component level
Design deficiency (i.e., sneak circuits, EMI, flow restriction)	Incipient change of state due to inherent characteristics	Assure design adequacy in development test sequences Tests at subassembly and assembly level bread-board and prototype
Overstress	Induced change of state	Assure adequacy of over-load protection and design margins in development test sequence

All subsystem development testing will include a teardown and inspection phase to the extent practical. The degree of teardown and inspection will be individually defined for each subsystem. Incipient failures may not be identified during the actual test conducted; therefore, a subsequent inspection of the test hardware is justified to identify those areas where high wear or other potential failure modes may exist. These data are then available for application to subsequent malfunction investigations.

The resultant major test articles required for development testing are identified in Tables 3-2 and 3.3. The utilization of the articles is illustrated in Figure 3-6.

Qualification Tests

The basic objective of qualification testing is to verify that equipment will function as required under the specified environmental conditions. As applied to the OLS program, qualification becomes an integral part of the launch confidence/assurance program. Qualification is a requirement that must be met by each component of every subsystem; a qualification matrix will be developed during the initial Phase C period of the OLS program. This matrix will define specific tests and/or analyses requirements for qualification of the OLS subsystems and will be based on realistic assessments of equipment functional and performance requirements. The matrix will list for each item of equipment, criticality, historical data, and tests to which it will be subjected.

Table 3-2. Core Module Subsystem Test Hardware Requirements

Equivalent OLS Subsystems										
Struct. Primary	Struct. Secondary	RCS	ENPS	EPS	ECLSS	IMS	G&C	Docking Provisions	Crew Habitability Equipment	Design Verification Testing
		Simulated Subsystems								Orbiting Lunar Station Mockup (Wood)
1.0(F)[3]	0.1(F)[3]		0.5(P)		0.3(P)[2]			0.2(P)		Structural Test Article
	0.5(P)	0.4(S)	0.2(S)	0.4(S)	0.3(S)	0.2(S)	0.5(S)	0.5(S)		Acoustical Test Article
0.75(P)	0.75(P)	0.7(S)		0.7(S)	0.8(S)	0.7(S)	0.7(S)			Dynamic Ground Test Vehicle
	0.75(P)	0.3(P)		1.0(P)[1]	0.7(P)	0.8(P)	0.9(P)	1.0(P)	0.5(P)	Compatibility Mockup
0.35(P)	0.50(P)	0.2(F)[3]		0.2(F)[3]	0.5(F)[3]	0.7(F)[3]				Thermal Integration Test Article [4]
0.2(P)	0.1(P)							1.0(P)		Docking Assurance Rig
0.0(F)	1.0(F)	1.0(F)	1.0(F)	1.0(F)[1]	1.0(F)	1.0(F)	1.0(F)	0.7(F)	1.0(F)	Mission Support Vehicle (Flight Spare)

LEGEND:

S = Simulated
P = Prototype
F = Flight

NOTES:

1. Does not include solar array
2. Pressurized compartment with control and relief valve
3. Utilized on MSV
4. Includes G&C acoustics testing

Table 3-3 . Experiment Module Subsystem Test Hardware Requirements

Equivalent OLS Subsystems					
Struct. Primary	Struct. Secondary	EPS	ECLSS	Docking	Design Verification Testing
← Simulated Subsystems →					OLS mockup (wood)
	0.75(P)	1.0(P)	0.7(P)	.7(P)	Compatibility mockup
1.0(F)	1.0(F)	1.0(F)	1.0(F)	0.7(F)	Mission support vehicle

P = Prototype

F = Flight

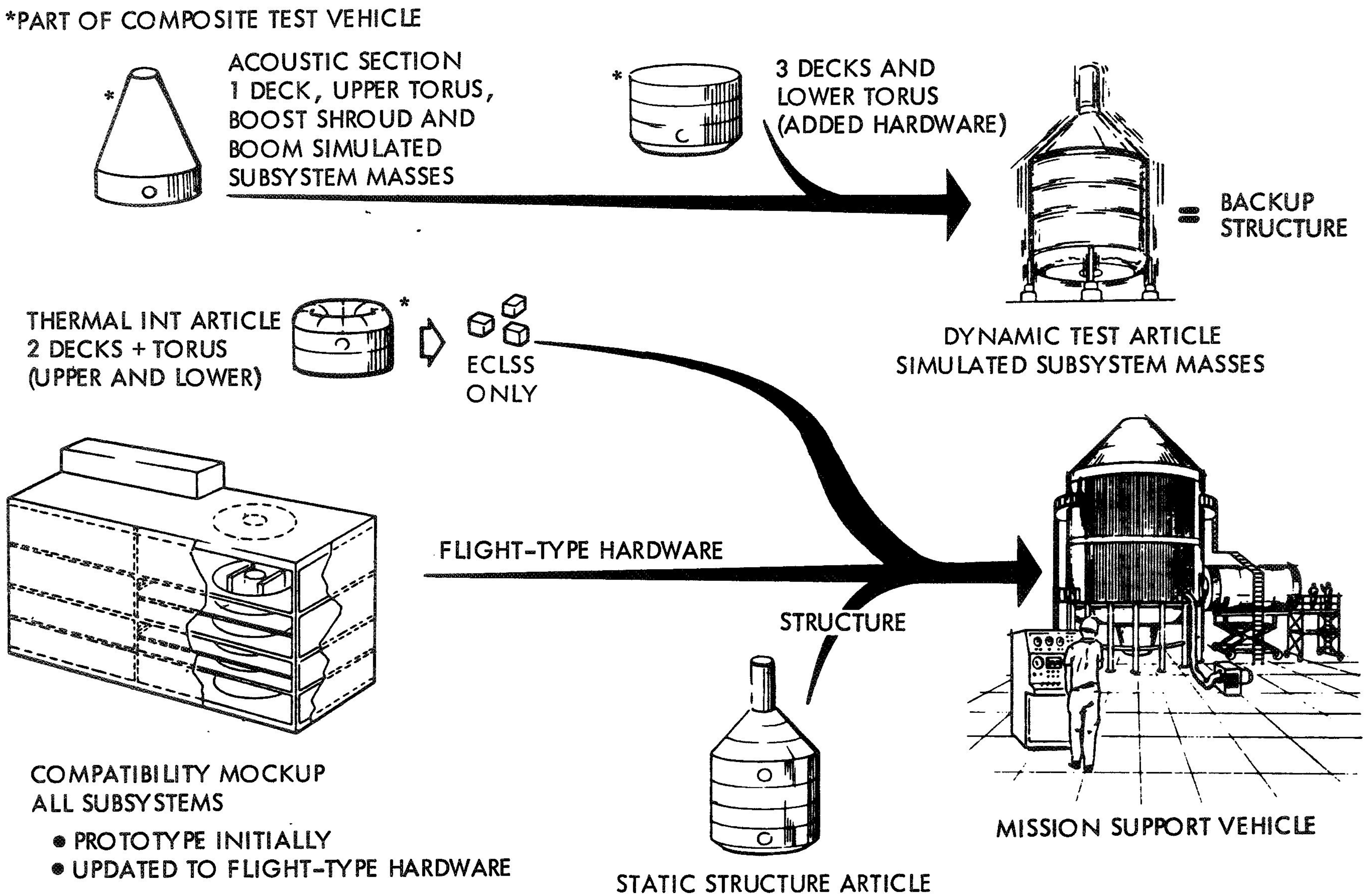


Figure 3-6. Representative OLS Test Article Utilization

The primary source of documentation will be a program data bank, which will provide the capability to call up all test and checkout history on each program hardware item. A launch confidence assurance matrix will be required to provide the control and management visibility necessary to assure timely accomplishment of the test requirements. This integrated matrix will identify the order and schedule of accomplishment of test objectives, thus it will prevent a force fit of test schedules and objectives to accommodate arbitrary gates or milestones.

Acceptance Tests

Acceptance testing is designed to verify that an article, ready for delivery to its next assembly or usage point, conforms to specifications with respect to configuration, quality, and performance. Acceptance test levels will encompass the full hardware range from piece parts or components (such as diodes-transistors) to the complete OLS core module. Many suppliers and subcontractors will be involved in the production of OLS equipment. Therefore, it is of prime importance that hardware acceptance specifications be established before initiation of procurement activities and that the acceptance specifications define the acceptance criteria explicitly. An acceptance specification tree such as shown in Figure 3-7 will standardize test documentation and assure compatibility of requirements (including performance requirements and tolerances) at each level of acceptance for each subsystem and for the complete core module. Tolerances do not tighten as the assemblies progress through subsequent levels of acceptance. The test criteria and rationale discussed in the following paragraphs under components, subsystems, and modules are based upon the previously discussed test philosophy.

Acceptance tests at the component/subassembly level will include flight-level environments plus a margin to assure that the accepted item will perform its required function in the anticipated operational environment. If a realistic assessment is made of the operational environment and adequate performance margins are incorporated into the requirements of the acceptance specification at the component/subassembly level, further need for qualification testing at this level can be minimized.

Each subsystem test program will include subsystem acceptance tests before installation. Subsystem performance will be determined within the operational ranges expected in flight. Dynamic interfaces with other subsystems will be simulated to the extent practical with bench-level equipment. These tests, performed with flight hardware, will minimize the total test effort on the flight vehicle necessary to demonstrate its flight readiness.

Acceptance testing at the subsystem level (installed in program elements) will include a demonstration of alternate/redundant modes of operation, together with the malfunction switching logic, by exercise of ISS onboard checkout subroutines. Alternate/redundant path checkout capability, via malfunction simulation, will be a subsystem checkout feature whenever this can be done without disturbing the flight configuration.

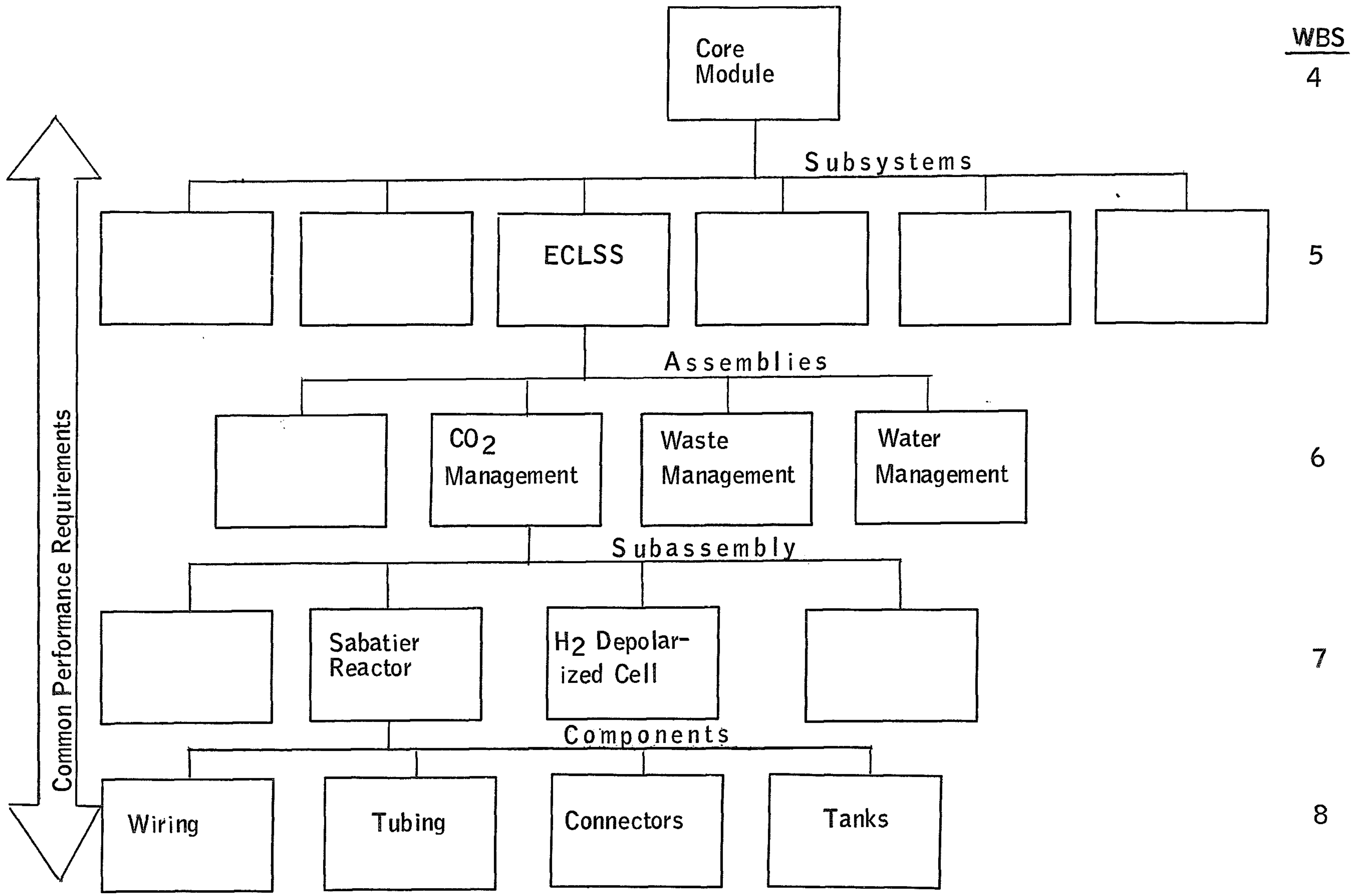


Figure 3-7. Proposed Example Acceptance Specification Tree

Electromagnetic compatibility (EMC) will be established at the design level and verified in the normal test and checkout sequence. Integrated tests in the development and acceptance cycle will verify that no electromagnetic interference (EMI) problems exist.

Vacuum testing of a complete program element (core module, experiment module, etc.) will not be required. Development/acceptance vacuum tests at the submodular or modular assembly level are now sufficient with the current state of the art. However, the entire structure will undergo pneumostat tests, followed by periodic pressure checks.

Acceptance of subsystems or In-Flight Replaceable Units (IFRU's) not operating during launch will include functional tests after the items have been subjected to the simulated launch environment. In the establishment of acceptance criteria, consideration will be given to operating versus passive modes. An example is the solar arrays. Launch environment will be applied in the stowed configuration, not in the deployed configuration.

The ISS onboard checkout capability will be used as the basis for acceptance testing of OLS subsystems and IFRU's. The ISS is designed to provide orbital checkout, and the inherent onboard checkout capability will be adequate for acceptance testing at the subsystem or IFRU level during factory/prelaunch testing. This will result in a significant reduction in ground test time and GSE requirements.

Acceptance testing at the modular level of the core module, power module, and experiment module will begin with subsystems installations and conclude with launch. Module test requirements are illustrated in Figure 3-8.

After subsystem installation in the modules, subsystems interfaces will be verified utilizing ISS onboard checkout capability. GSE and facility verification will be required before flight subsystem interface checks. The interface between the electrical power subsystem (EPS) and the ISS will be determined first. Other subsystems interface checks will follow until all internal electrical subsystem interface checks are completed. Electromechanical interface checks of the power boom, boost shroud, flight crew items, and cargo will also be included.

Consoles will be located in a control center and will be capable of reading out appropriate module test information and providing limited test control procedures. The consoles will be connected to the module data bus through a removable umbilical.

By simulating all mission phases through initial operations, the module integrated test will demonstrate that subsystems are operating within specifications, including subsystem electromagnetic compatibility. The test will provide the overall program confidence required for customer acceptance of the modules and will verify the readiness for shipment of the modules to the prelaunch assembly site.

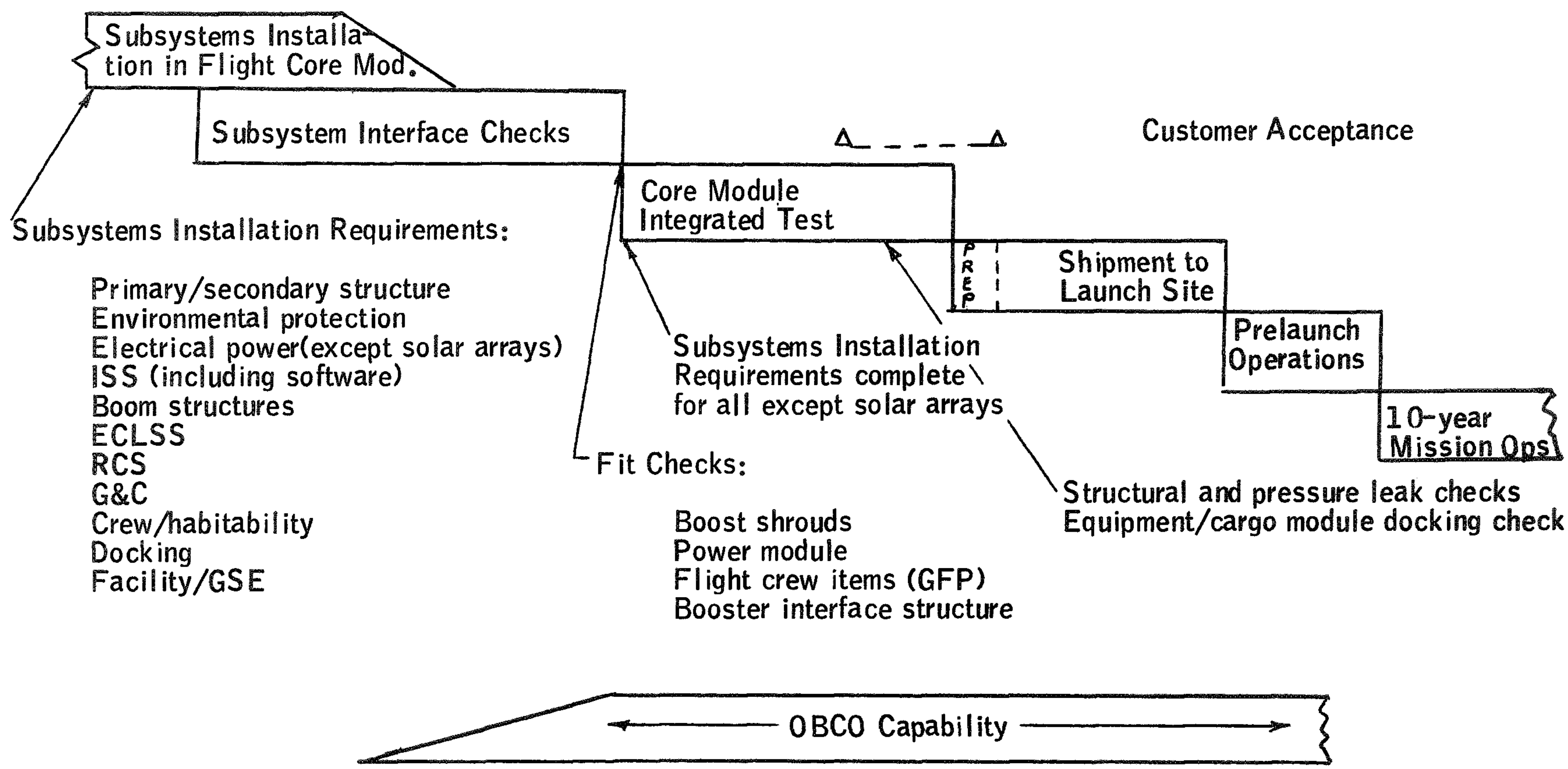


Figure 3-8. Module Test Requirements

In the case of the core module, subsystems will be controlled and evaluated from the onboard command and control center, which will demonstrate its backup capability. All subsystems will demonstrate all modes and electrical paths using the OBCO capability provided by the ISS with flight crew participation. Required utilities will be provided by the acceptance and delivery site through a removable umbilical. Leak checks of primary structure and associated plumbing will be required. Verification of experiment operation will also be required.

At the prelaunch site the OLS core module and power module will be mated with the launch vehicle. The space vehicle (OLS core module, power module, and launch vehicle) will be moved to the launch site. A combined OLS launch vehicle countdown will be conducted culminating with launch and earth orbital insertion of the OLS.

In the case of the experiment module, upon completion of acceptance testing it will be transported to the shuttle launch site and installed in the shuttle cargo bay. Testing of the module installed in the shuttle cargo bay is not required.

3.2.3 Facility Requirements

The OLS development test program will require use of several test facilities. The most significant ones are briefly described in the following paragraphs.

A structural test facility will be required that will be large enough to accommodate the complete core module along with loading devices necessary to conduct a static structure program. The facility must be capable of structural tests for items ranging from structural panels and secondary structure to the total module structure. Requirements include both static loading at ambient temperatures and at elevated temperatures.

For certain tests, a large thermal vacuum chamber will be required. The chamber must be large enough to accommodate the major thermal-integration test article, which will be full diameter and two floors plus the upper torus. The chamber must have the space characteristics approximately equivalent to the present thermal vacuum chamber at MSC, Houston.

Acoustic tests of structural panels and major structural subassemblies will require two facilities. A small facility will be required to subject structural components and subassemblies to the boost environment. In addition, a facility will be required that is sufficiently large to house the upper section of the station while subjecting it to the acoustic boost environment. This large test article will consist of the upper floor, torus, power boom, and boost shroud. Acoustic levels approximating the boost environment will be required.

OLS development will also require the use of engineering laboratories with extensive capabilities. The following list of required tests indicates the multi-discipline laboratories that will be required.

1. Static tests and combined static and temperature tests
2. Vibration and acoustic tests
3. Thermal vacuum tests including a simulated ascent profile
4. Separation tests utilizing pyrotechnics
5. Materials suitability
6. Micrometeoroid impact simulation
7. Electromagnetic compatibility
8. Electrical loads
9. Fluid handling, storage and transfer
10. Mechanical functional evaluation
11. Evaluation of cryogenic handling, storage, and transfer
12. Six-degree-of-freedom zero-gravity control simulations

The combined and integrated tests will require a special facility. This facility must be capable of containing all OLS modules. The facility or structure must allow ready access to components and subassemblies of the modules and must not be more restrictive than the station for their maintenance and replacement.

3.2.4 Hardware Utilization List

Based upon the hardware tree in Section 3.1, the development test requirements, and operational requirements, Hardware Utilization Lists (HUL's) for the core and experiment modules of the representative OLS are presented in Tables 3-4 and 3-5. The HUL's for these modules indicate simulated, prototype, and flight hardware requirements. Prototype hardware for the test articles are listed as an estimated decimal equivalent of the total equipment required for flight. Table 3-6 presents the HUL for the power module. It is limited to only the operational hardware because of the similarity between the MSS and OLS power module concepts.

Table 3-4. Core Module HUL

	Mockup	Structural Test	Acoustical Test	Dynamic Test	Compatibility Mockup	Thermal Test	Docking Assurance	Mission Support Vehicle	Operational Hardware
Primary Structure	1(S)	1.0(F)	-	0.75(P)	-	0.35(P)	0.2(P)	1.0(F)[1]	1(F)
Secondary Structure	1(S)	0.1(F)	0.5(P)	0.75(P)	0.75(P)	0.5(P)	0.1(P)	1.0(F)	1(F)
RCS	1(S)	-	0.4(S)	0.7(S)	0.3(P)	0.2(F)	-	1.0(F)	1(F)
ENPS	1(S)	0.5(P)	0.2(S)	-	-	-	-	1.0(F)	1(F)
EPS	1(S)	-	0.4(S)	0.7(S)	1.0(P)	0.2(F)	-	1.0(F)	1(F)
ECLSS	1(S)	0.3(P)	0.3(S)	0.8(S)	0.7(P)	0.5(F)	-	1.0(F)	1(F)
ISS	1(S)	-	0.2(S)	0.7(S)	0.8(P)	0.7(F)	-	1.0(F)	1(F)
G&C	1(S)	-	0.5(S)	0.7(S)	0.9(P)	0.7(F)	-	1.0(F)	1(F)
Docking	1(S)	0.2(P)	0.5(S)	-	1.0(P)	-	1.0(P)	0.7(F)	1(F)
Crew Habitability	-	-	-	-	0.5(P)	-	-	1.0(F)	1(F)

LEGEND:

S = Simulated
P = Prototype
F = Flight

NOTES:

1. Reused after structural test
2. Thermal test hardware is reused on the MSV

Table 3-5. Experiment Module HUL

	Mockup	Compatibility Mockup	Mission Support Vehicle	Operational Hardware
Primary Structure	1(S)	-	1(F)	1(F)
Secondary Structure	1(S)	0.75(P)	1(F)	1(F)
ENPS	1(S)	-	-	1(F)
EPS	1(S)	1.0(P)	1(F)	1(F)
ECLSS	1(S)	0.7(P)	1(F)	1(F)
Docking	1(S)	0.7(P)	0.7(F)	1(F)

LEGEND:

S = Simulated

P = Prototype

F = Flight

Table 3-6. Power Module Hardware Utilization List

	Operational Hardware
Structure	1
ENPS	1
EPS	1
ECLSS	1
ISS	1
Docking	1

3.3 PROGRAM DEVELOPMENT SCHEDULE

Presented in the following paragraphs is the representative OLS program development schedule. This schedule considers both manufacturing and test operations from initiation of Phase B activities to OLS IOC. Manufacturing schedules for the OLS hardware are developed and integrated into a detailed schedule which is derived by working back, in time, from the 1983 OLS IOC date.

3.3.1 Manufacturing Schedules

Assumptions used in developing schedules for the representative OLS are basically similar to those used on the Earth Orbital Space Station (EOSS) Program. The structure is assumed to be similar to that used in the Saturn S-II stage, with assembly taking place in a facility similar to the NASA Seal Beach Facility, using the existing work stations to the greatest degree possible.

The primary structure is composed of cylinders welded up from large formed panels with integral machined stiffeners, using bonded honeycomb sandwich bulkheads for floors, ceilings, and the pressure barrier between the two volumes of the station. End closures of the pressure volumes are toroidal bulkheads, consisting of high energy formed gores welded together. Buildup of the cylinders is virtually identical to S-II fabrication except that the integral stiffeners are on the outside surface for the OLS; the existing work station would need some modification to accommodate the smaller diameter of the OLS, with the majority of the welding tools usable as is. Welding of the toroidal bulkheads will require new tooling; the work stations, welding equipment, and test equipment are on hand. Bonding of the bulkheads will be accomplished in the existing autoclave.

The Core Module Flow Plan (Figure 3-9) indicates the timespan, in months, required to fabricate, assemble, and checkout a complete representative OLS. The flow times shown are based on experience in the serial production of the Saturn S-II stage, which uses a very similar construction method. Unique items, such as the toroidal bulkheads, have been subjected to a schedule analysis based upon in-house experience with high-energy forming of large shapes, welding of large-diameter formed bulkheads, and non-destructive inspection and testing techniques.

Figure 3-10 presents a composite of both manufacturing and test operations. The sequencing and calendar dates for the fabrication, assembly and test of all major items identified in the HUL's are presented. Timespans for the various test articles vary in length to reflect the amount of structure to be fabricated, or the system to be installed, in a particular item. They are based on a selective two-shift, five day work week, on essentially one set of structural fabrication tooling and a sequential buildup concept.

Assembly sequences were based upon scheduling data from the Saturn S-II program. System installation timespans were extrapolated from Apollo experience, with allowances made for the increased complexity of the equipment. To some degree this was offset by the planned increase in accessibility to the installation work stations. Launch operations flow time was reduced to reflect the use of the on-board checkout capability of the OLS ISS.

3.3.2 Detailed Program Development Schedule

The detailed program development schedule shown in Figure 3-11 presents an integrated set of activities and major milestones from the initiation of Phase B to the OLS IOC date. It schedules definition, design, development, fabrication, and test of all major articles of the representative OLS. The schedule is predicated on the OLS definition in Volume V of this report.

The groundrules used in the development of this schedule are:

1. Existing contractor and government facilities will be used wherever possible; requirements for additional facilities or modified facilities and related equipment will be minimized.

2. The representative OLS contractor may or may not be the MSS contractor.

3. A six month NASA evaluation period will occur between Phase B and Phase C/D.

4. A single contract will be awarded for Phase C, design, and Phase D, development/operations; Phase D will immediately follow Phase C.

5. Launch will be on 1 June 1983 from the Kennedy Space Center. IOC will be established on 1 December 1983.

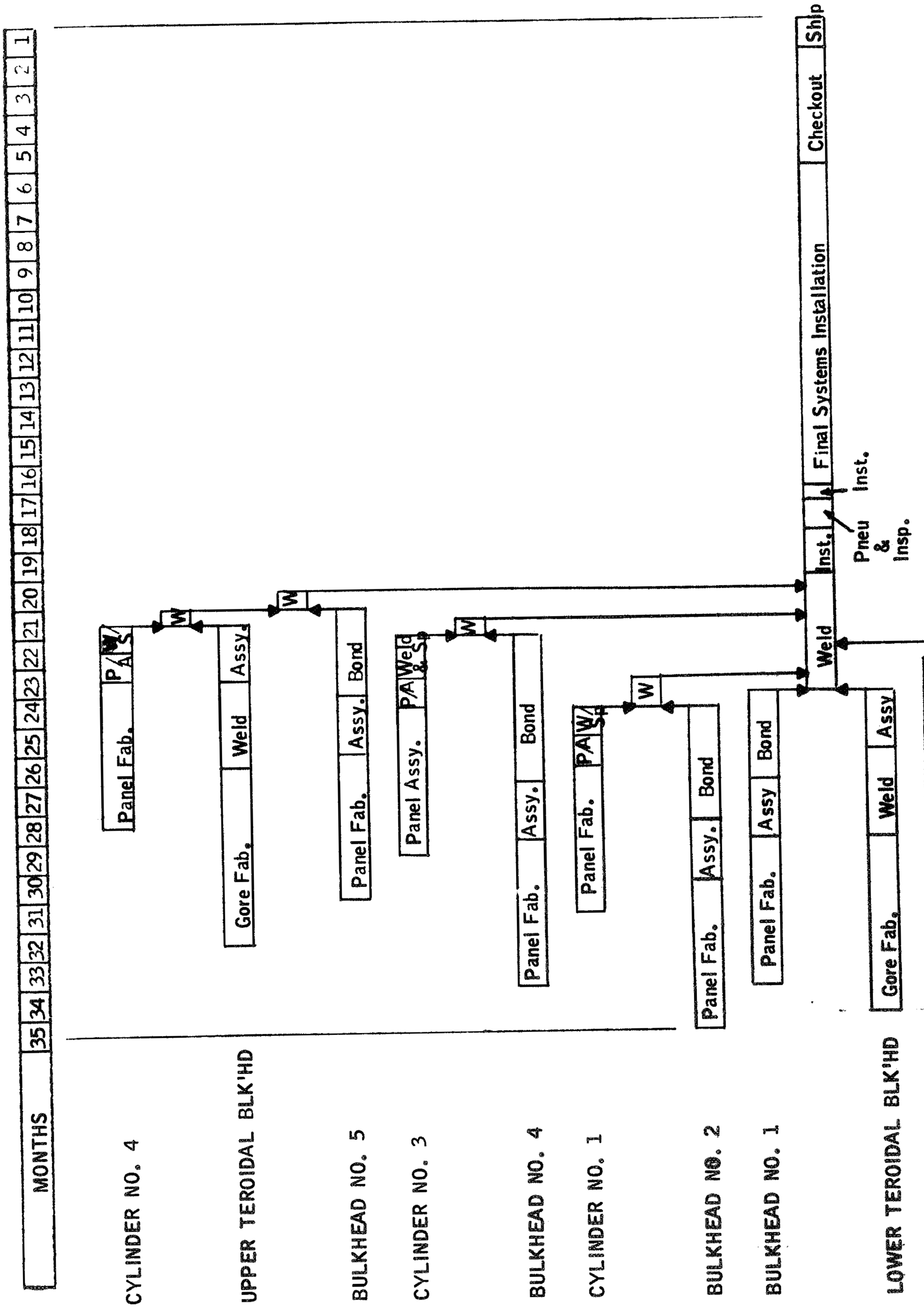


Figure 3-9. Representative OLS Manufacturing Schedule (Flight Core Module Schedule)

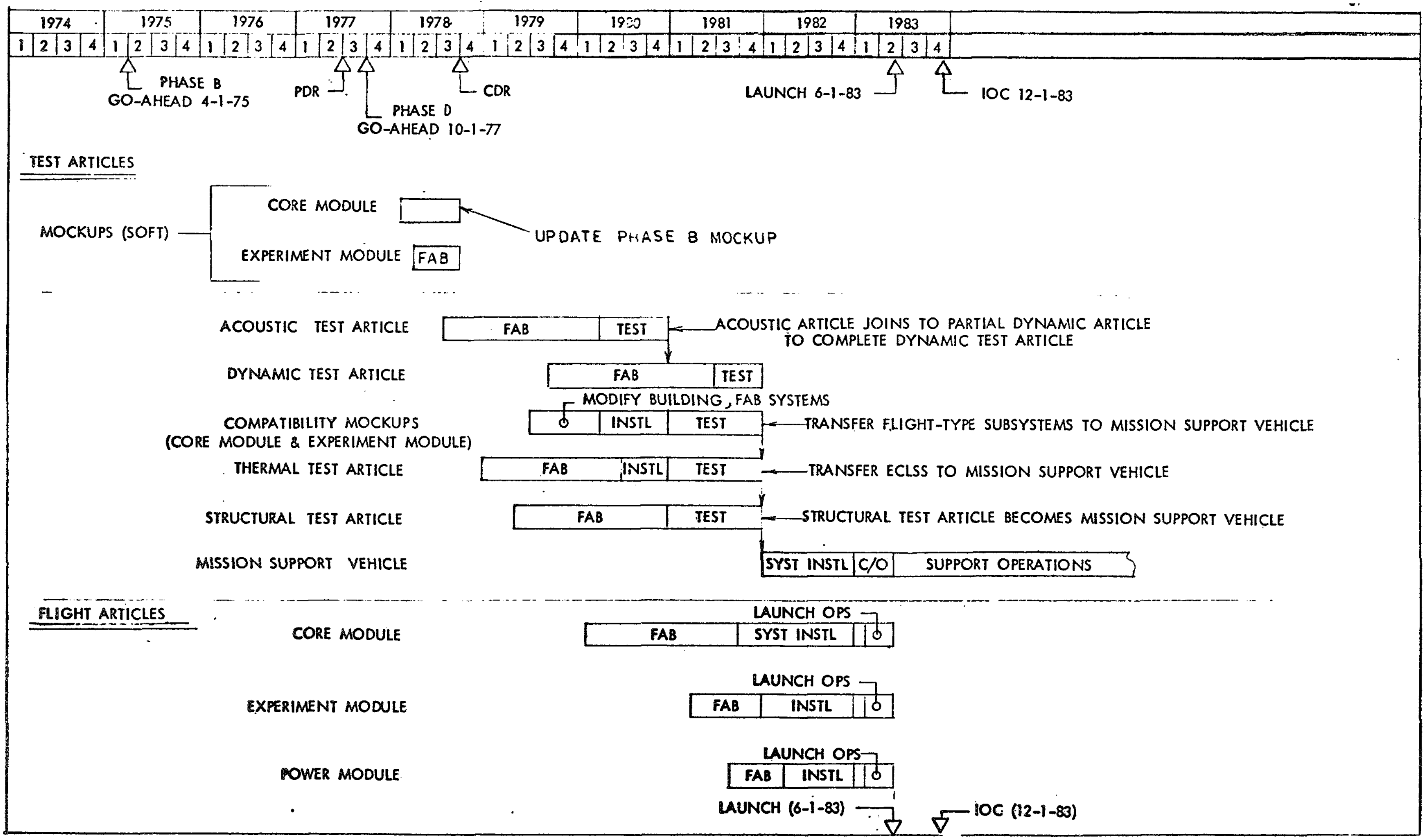
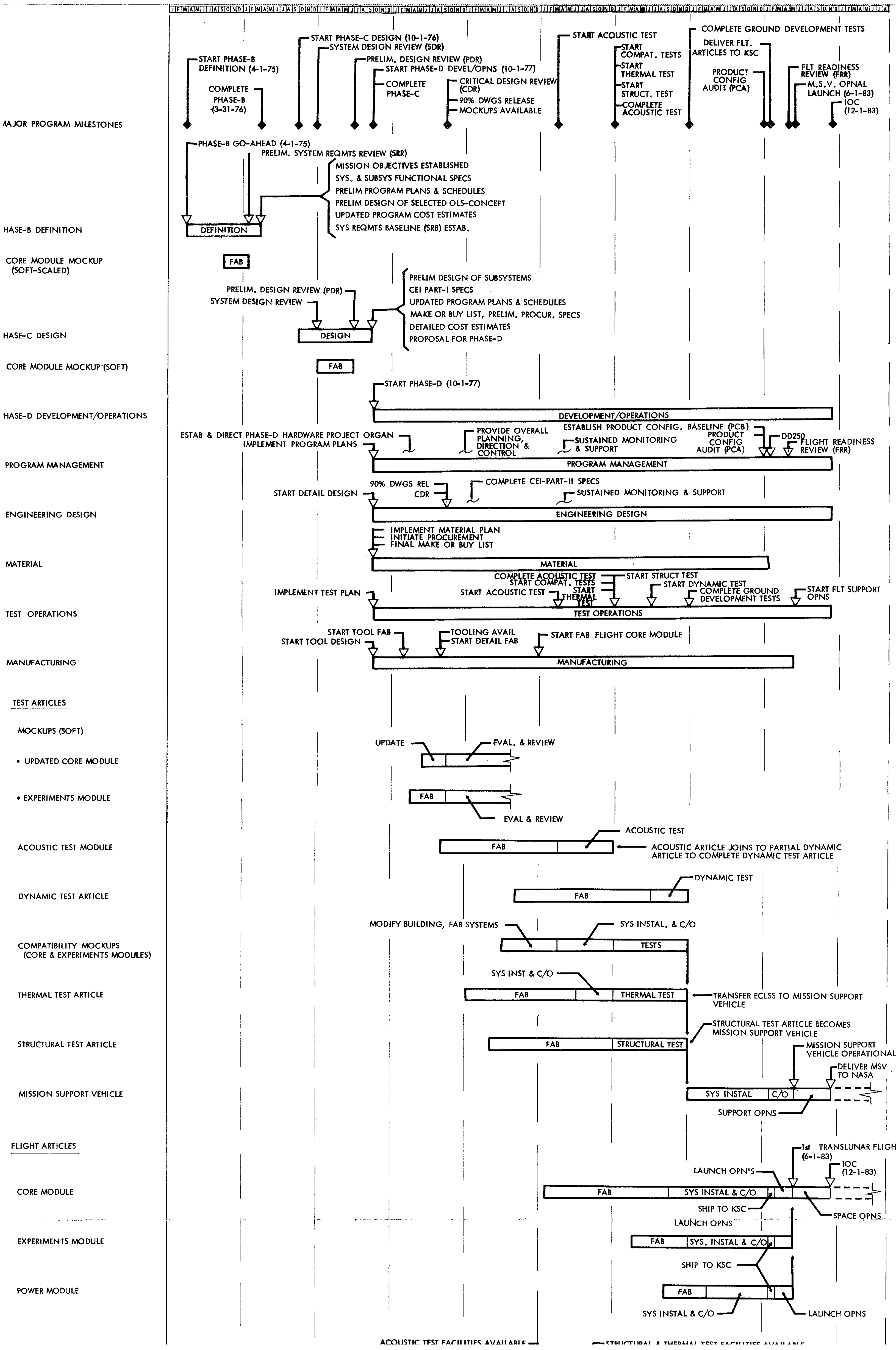


Figure 3-10. Orbiting Lunar Station Study Manufacturing Composite Assembly Schedule Representative (27-foot diameter) OLS



J F M A M J J A S O N D
MAJOR PROGRAM MILESTONES
START PHASE-B DEFINITION (4-1-75)
COMPLETE PHASE-B (3-31-76)
START PHASE-C DESIGN (10-1-76)
SYSTEM DESIGN REVIEW (SDR)
PRELIM. DESIGN REVIEW (PDR)
START PHASE-D DEVEL/OPNS (10-1-77)
COMPLETE PHASE-C
CRITICAL DESIGN REVIEW (CDR)
90% DWGS RELEASE
MOCKUPS AVAILABLE
START ACOUSTIC TEST
START COMPAT. TESTS
START THERMAL TEST
START STRUCT. TEST
COMPLETE ACOUSTIC TEST
COMPLETE GROUND DEVELOPMENT TESTS
DELIVER FLT. ARTICLES TO KSC
PRODUCT CONFIG AUDIT (PCA)
FLT READINESS REVIEW (FRR)
M.S.V. OPNAL LAUNCH (6-1-83)
IOC (12-1-83)
PHASE-B DEFINITION
PHASE-B GO-AHEAD (4-1-75)
PRELIM. SYSTEM REQMTS REVIEW (SRR)
MISSION OBJECTIVES ESTABLISHED
SYS. & SUBSYS FUNCTIONAL SPECS
PRELIM PROGRAM PLANS & SCHEDULES
PRELIM DESIGN OF SELECTED OLS-CONCEPT
UPDATED PROGRAM COST ESTIMATES
SYS REQMTS BASELINE (SRB) ESTAB.
DEFINITION
CORE MODULE MOCKUP (SOFT-SCALED)
FAB
PHASE-C DESIGN
PRELIM. DESIGN REVIEW (PDR)
SYSTEM DESIGN REVIEW
PRELIM DESIGN OF SUBSYSTEMS
CEI PART-I SPECS
UPDATED PROGRAM PLANS & SCHEDULES
MAKE OR BUY LIST, PRELIM. PROCUR. SPECS
DETAILED COST ESTIMATES
PROPOSAL FOR PHASE-D
DESIGN
CORE MODULE MOCKUP (SOFT)
FAB
PHASE-D DEVELOPMENT/OPERATIONS
START PHASE-D (10-1-77)
DEVELOPMENT/OPERATIONS
PROGRAM MANAGEMENT
ESTAB & DIRECT PHASE-D HARDWARE PROJECT ORGAN
IMPLEMENT PROGRAM PLANS
PROVIDE OVERALL PLANNING, DIRECTION & CONTROL
SUSTAINED MONITORING & SUPPORT
ESTABLISH PRODUCT CONFIG. BASELINE (PCB)
PRODUCT CONFIG AUDIT (PCA)
DD250
FLIGHT READINESS REVIEW (FRR)
PROGRAM MANAGEMENT
ENGINEERING DESIGN
START DETAIL DESIGN
90% DWGS REL
CDR
COMPLETE CEI-PART-II SPECS
SUSTAINED MONITORING & SUPPORT
ENGINEERING DESIGN
MATERIAL
IMPLEMENT MATERIAL PLAN
INITIATE PROCUREMENT
FINAL MAKE OR BUY LIST
MATERIAL
TEST OPERATIONS
IMPLEMENT TEST PLAN
START ACOUSTIC TEST
COMPLETE ACOUSTIC TEST
START COMPAT. TESTS
START THERMAL TEST
START STRUCT TEST
START DYNAMIC TEST
COMPLETE GROUND DEVELOPMENT TESTS
START FLT SUPPORT OPNS
TEST OPERATIONS
MANUFACTURING
START TOOL FAB
START TOOL DESIGN
TOOLING AVAIL
START DETAIL FAB
START FAB FLIGHT CORE MODULE
MANUFACTURING
TEST ARTICLES
MOCKUPS (SOFT)
• UPDATED CORE MODULE
UPDATE
EVAL. & REVIEW
• EXPERIMENTS MODULE
FAB
EVAL & REVIEW
ACOUSTIC TEST MODULE
FAB
ACOUSTIC TEST
ACOUSTIC ARTICLE JOINS TO PARTIAL DYNAMIC ARTICLE TO COMPLETE DYNAMIC TEST ARTICLE
DYNAMIC TEST ARTICLE
FAB
DYNAMIC TEST
COMPATIBILITY MOCKUPS (CORE & EXPERIMENTS MODULES)
MODIFY BUILDING, FAB SYSTEMS
SYS INSTAL. & C/O
TESTS
THERMAL TEST ARTICLE
SYS INST & C/O
FAB
THERMAL TEST
TRANSFER ECLSS TO MISSION SUPPORT VEHICLE
STRUCTURAL TEST ARTICLE
FAB
STRUCTURAL TEST
STRUCTURAL TEST ARTICLE BECOMES MISSION SUPPORT VEHICLE
MISSION SUPPORT VEHICLE
MISSION SUPPORT VEHICLE OPERATIONAL
DELIVER MSV TO NASA
SYS INSTAL
C/O
SUPPORT OPNS
FLIGHT ARTICLES
CORE MODULE
1st TRANSLUNAR FLIGHT (6-1-83)
IOC (12-1-83)
LAUNCH OPN'S
FAB
SYS INSTAL & C/O
SHIP TO KSC
SPACE OPNS
EXPERIMENTS MODULE
LAUNCH OPNS
FAB
SYS. INSTAL & C/O
SHIP TO KSC
POWER MODULE
FAB
SYS INSTAL & C/O
LAUNCH OPNS
ACOUSTIC TEST FACILITIES AVAILABLE
STRUCTURAL & THERMAL TEST FACILITIES AVAILABLE

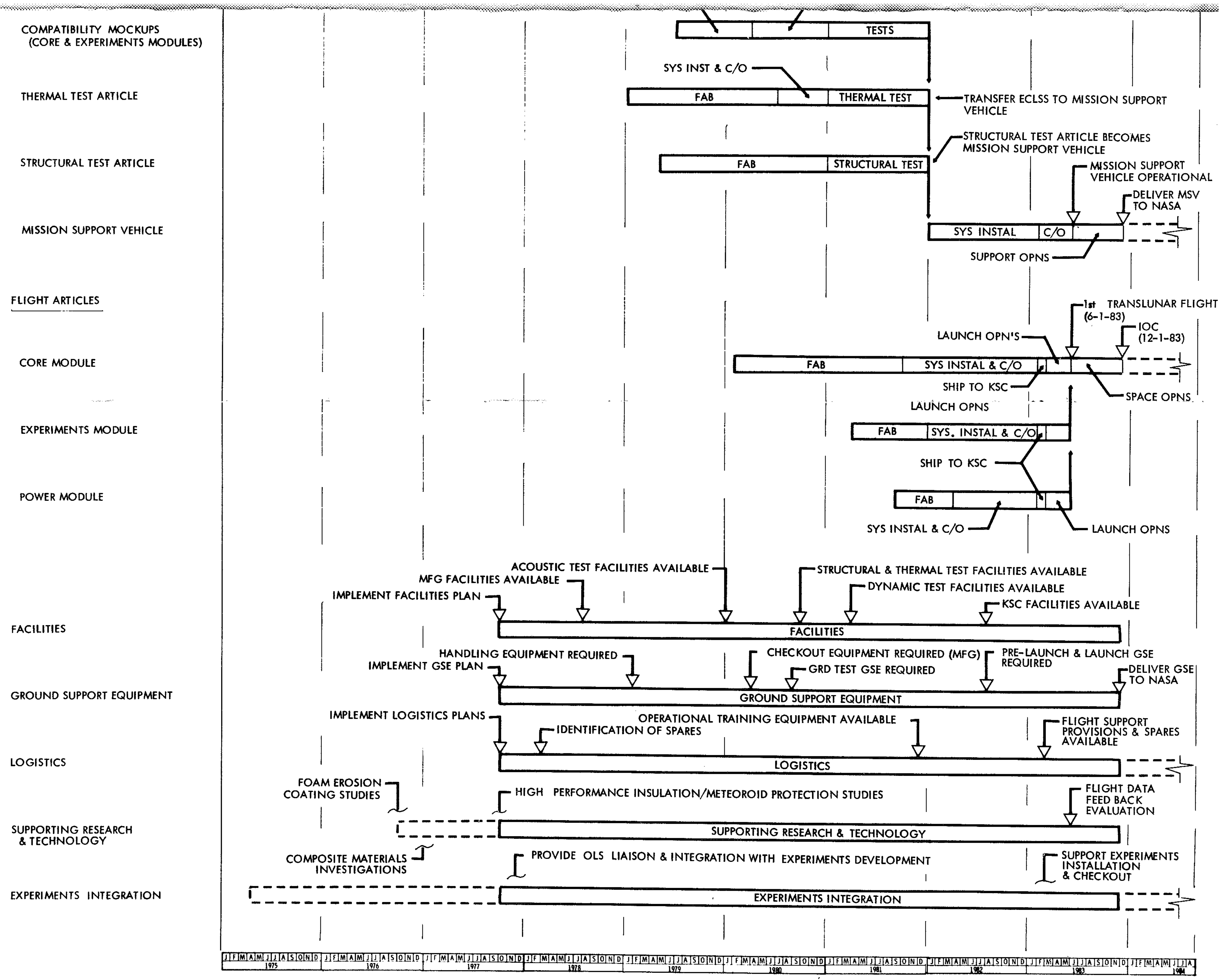


FIGURE 3-11. REPRESENTATIVE OLS PROGRAM DEVELOPMENT SCHEDULE

The phasing and significant accomplishments of the program are as follows:

1. A 12-month Phase B definition will start on April 1, 1975. During this study period, the major accomplishments will include:

    a. System Requirements Baseline (SRB) established

    b. Mission objectives established

    c. System and subsystem functional specifications prepared

    d. Preliminary program plans and schedules prepared

    e. Preliminary design of selected OLS concept

    f. Updated program cost estimates

    The completion of the definition study will be followed by a 6-month customer review and evaluation period.

2. Phase C design will start on October 1, 1977 and last for 12-months. Major accomplishments during the design study phase will include:

    a. Preliminary design of subsystems

    b. CEI Part I specifications prepared

    c. System Design Review (SDR)

    d. Updated programs plans and schedules

    e. Make-or-buy list prepared

    f. Preparation of procurement specifications

    g. Preliminary Design Review (PDR)

    h. Detailed program cost estimates

3. Phase D development operations will commence immediately upon the completion of Phase C (October 1, 1977).

4. The total time from the start of Phase D to launch is 68 months. IOC is scheduled six months after launch on December 1, 1983.

The schedule shows that during the Phase B definition study, an Orbiting Lunar Station soft mockup (scaled) will be fabricated with completion to coincide with the preliminary System Requirements Review (SRR). A full size core module mockup is scheduled for fabrication during Phase C to be available for the Preliminary Design on July 1, 1977. This mockup will be updated and available for the Critical Design Review (CDR) during Phase D.

For Phase D development/operation the program development schedule depicts the major milestones for each of the principal program functions. Program plans will be updated and implemented as soon as possible after Phase D go-ahead. Project management will implement the schedule and cost and technical performance functions. Detailed development and production design effort will begin at the start of Phase D. The Critical Design Review (CDR) is scheduled at 12 months after the start of Phase D, at which time 90 percent of the detail drawings are scheduled for release. An experiments module soft mockup is scheduled for completion for the Critical Design Review.

The manufacturing function covers a time span of approximately four years with fabrication, assembly, system installation, and checkout as applicable for the mockups, test articles, and flight hardware. Time spans for the various test articles vary in length depending on the amount of structure to be fabricated or systems to be installed. As shown on the schedule, considerable savings in manufacture time and monetary cost is realized by the reutilization of test articles for additional testing. The Mission Support Vehicle utilizes the flight-rated hardware and structure from the thermal test article and the structural test article respectively.

The test operations activity bar shown on the program development schedule depicts approximate start and completion dates for the major program tests. Major ground tests are scheduled so as to make maximum utilization of the test articles. The ground testing program covers a span of 21 months. The sequence of major tests is as follows: acoustic test, thermal test, structural test, compatibility tests, and dynamic test.

The program development schedule shows activity bars along with some of the key milestones for material, facilities, ground support equipment (GSE), logistics, supporting research and technology, and experiments integration. Facilities milestones indicate when manufacturing and operational facilities will be available. GSE milestones indicate when test and launch GSE is required and when handling equipment is available. Logistics milestones show the need dates for training equipment, provisions, and spares. A typical supporting research and technology activity bar is shown which reflects pacing factors affecting new technology requirements. The experiment integration activity bar depicts the program requirement of providing OLS liaison and integration with experiments development. Detail program plans, schedules, and supporting documentation for the support functions shown on the schedule will be prepared during the Phase B definition study.

An evaluation of the overall preliminary program development schedule for the representative OLS indicates the schedule is optimistic in the sense that concurrency of activities is reflected throughout the program. The phasing of manufacturing and test activities and sequence of program milestones are good from the standpoint that a reasonable amount of time slack has been allowed for unforeseeable program delays and test failures.

3.4 WORK BREAKDOWN STRUCTURE

The Work Breakdown Structure (WBS) for the representative OLS (Figure 3-12) was jointly developed between NASA/MSC and NR personnel during the course of the study. It presents a hierarchy of levels illustrating the logical separation of a program into hardware elements. The OLS element is expanded into the principal categories of hardware, services, and related work tasks involved in its development down to the major subsystem level (level 5). The WBS together with the program development schedule provides the frame of reference for the preparation of program cost estimates.

The WBS is structured in a manner similar to WBS's of other current NASA programs. The hardware portion reflects the selected concept of the representative OLS and is subdivided into flight hardware and test hardware to facilitiate identification of development (non-recurring) and production (recurring) costs.

#1

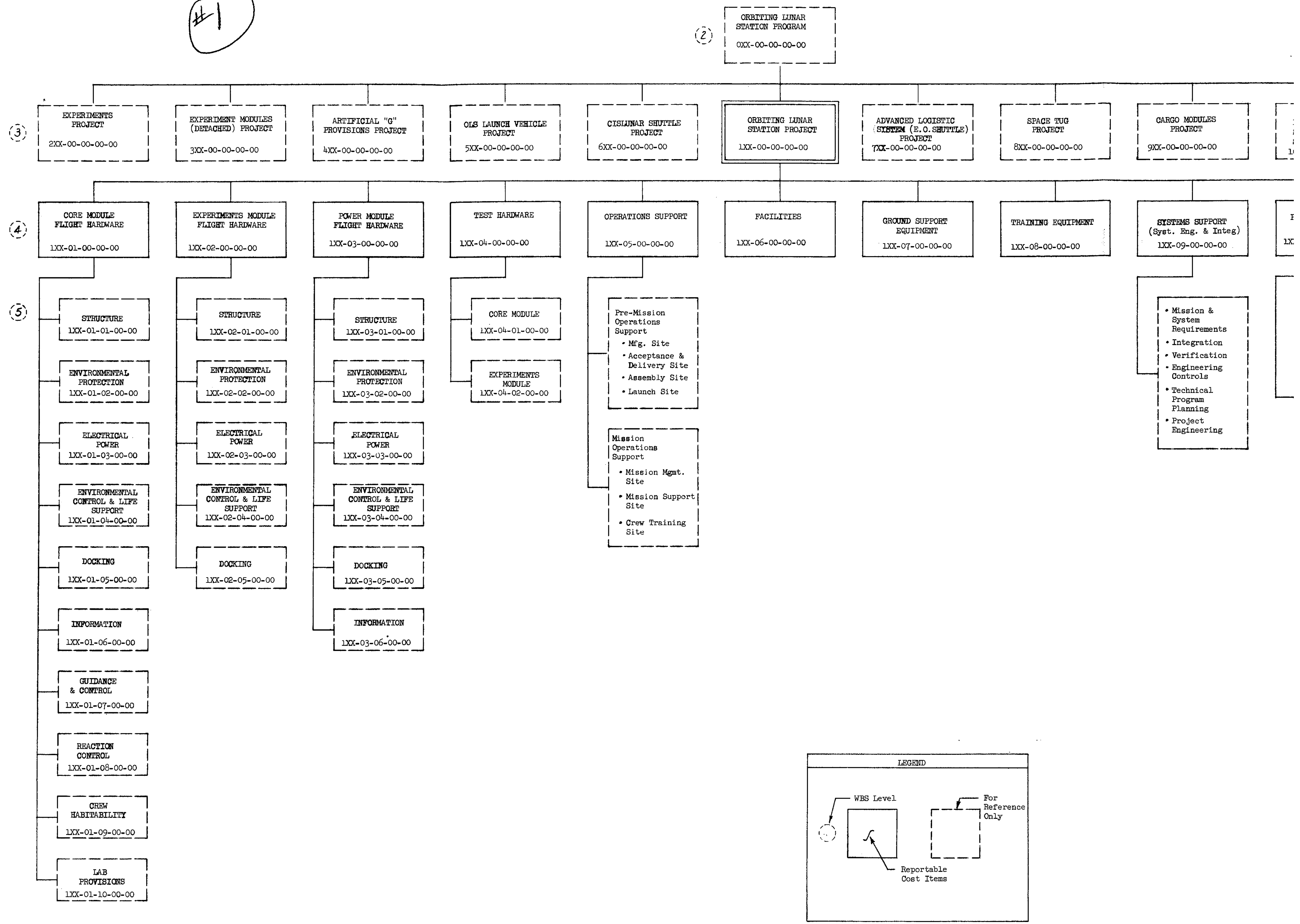
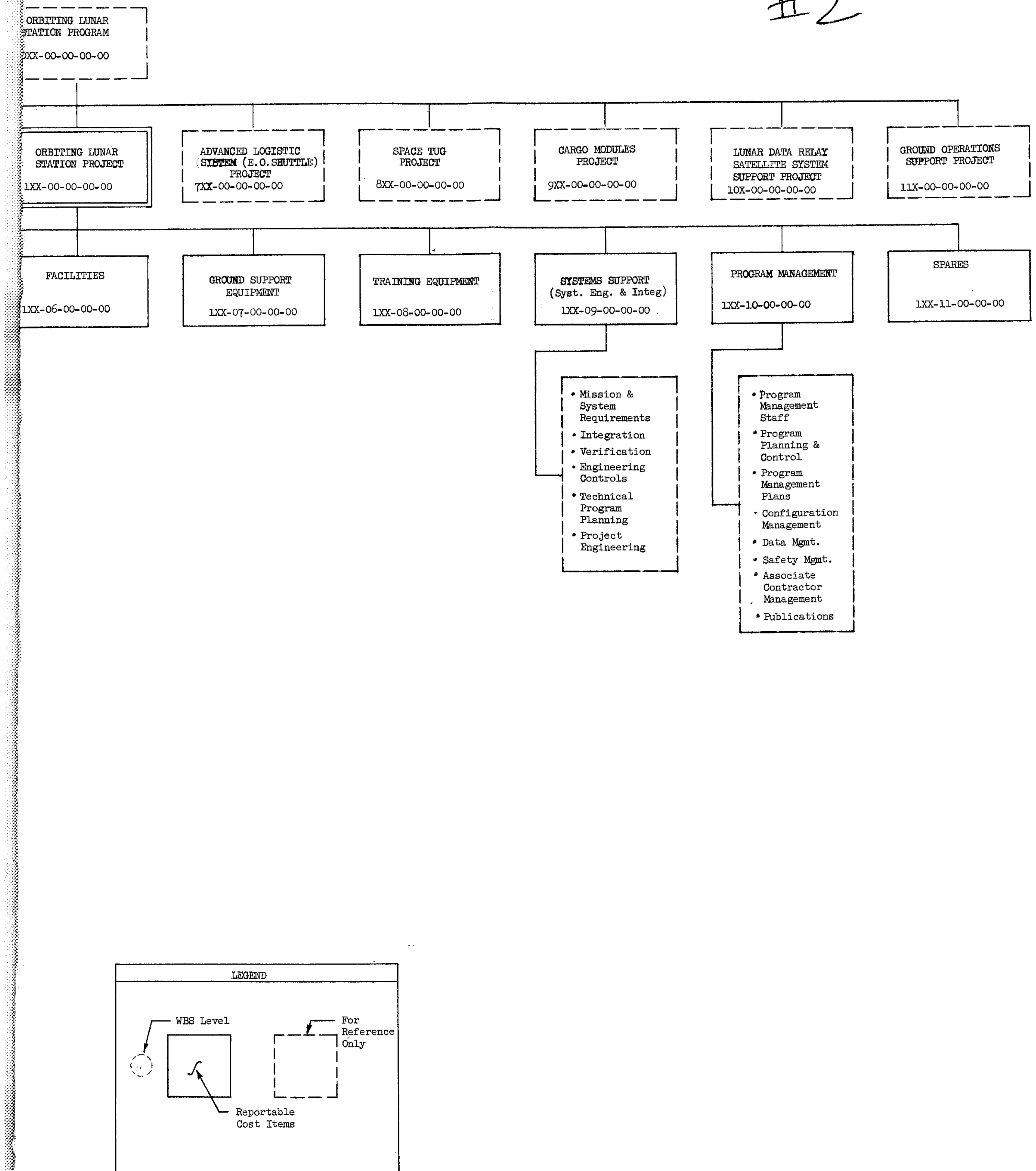


Figure 3-12. Work Breakdown Structure - Representative OLS

#2



Work Breakdown Structure - Representative OLS

3.5 PROGRAM COST ESTIMATES

This section contains budgetary and planning costs for the representative OLS. A technical description of the representative OLS is presented in Volume V of this report. The data presented herein contain cost, schedule and technical characteristics and were prepared in accordance with the NASA instructions in the Data Requirement Description of DRL line item 1, enclosed with the statement of work of this study.

The work breakdown structure (WBS), of Figure 3-12, provided the frame of reference for estimating and reporting cost and the system element level (WBS level 4). The program development schedule and plan, Figure 3-11, provided the basis for deriving all yearly funding estimates.

3.5.1 Costing Ground Rules

The significant ground rules and assumptions employed in the cost analysis for the OLS Program are as follows:

1. Costs reflect GFY 1970 dollars and include all elements of cost through general and administrative (G&A) level. Contractor fee is excluded from this Phase A analysis.

2. Costs are intended for budgetary and planning purposes only and do not constitute a firm commitment on the part of North American Rockwell Corporation.

3. Nonrecurring cost includes design and development, major test hardware, captive and ground test, tooling and special test equipment, test and operations, ground support equipment, facilities, training equipment and simulators and miscellaneous other costs.

4. Recurring production cost includes flight hardware, acceptance test, sustaining tooling and special test equipment, sustaining ground support equipment, launch operations and services, initial flight spares and miscellaneous other costs

5. A solar-powered modular space station (MSS) has been developed and is operational during Phase D of the OLS Program.

6. Module cost estimates are based on estimated dry weights and subsystem complexities allowing for commonality throughout all modules.

7. All cost and schedule requirements are based on the representative OLS configuration as described in Volume V of this report.

8. The representative OLS weight statement contained in Volume V of this report provided the baseline for all cost projections.

9. Costs excluded from this analysis are as follows:

   a. Supporting research and technology

   b. All consumables

   c. Government facilities

   d. All NASA costs, e.g., MSC, KSC, Mission Control, DRSS/MSFN, crew training, mission support, etc.

   e. No flight test anticipated or costed, e.g., solar array/deployment

   f. Foods, medical and dental supplies, clothing, personal gear, space suits, EVA equipment, etc.

   g. Subsatellites and scientific instruments

10. Costs are based upon the assumption that the OLS Program may not be conducted by the same contractor that conducted the MSS Program.

11. Operations support costs cover contractor effort through IOC only.

12. Spares and replacements for 10 years operation will be delivered prior to IOC.

13. The active-active docking adapters are airborne equipment and costed under GSE.

3.5.2 Cost Methodology

The methodology used to estimate the cost of the OLS program was by parametric techniques. A technical comparison was made for each OLS subsystem (WBS level 5) relative to the equivalent Earth Orbital Space Station (EOSS) subsystem and complexity factors derived for development and production. The factors, especially in the development areas, gave consideration to space hardware qualified on the MSS program (reference costing ground rule 5). The EOSS program was chosen for comparative purposes for several reasons; e.g., (1) a 33-foot diameter core module is used on the EOSS versus a 27-foot diameter on the OLS, (2) 10,000 square feet solar array primary power sources are used on both programs, and (3) a Phase B definition study contract, NAS9-9953, just completed on EOSS provides a reasonable and high confidence cost baseline.

Cost estimating relationships (CER's) developed during the previously mentioned EOSS study provided the baseline subsystem CER's to which OLS complexity and weight factors were applied to derive the costs reported herein.

3.5.3 Summary Cost Estimates

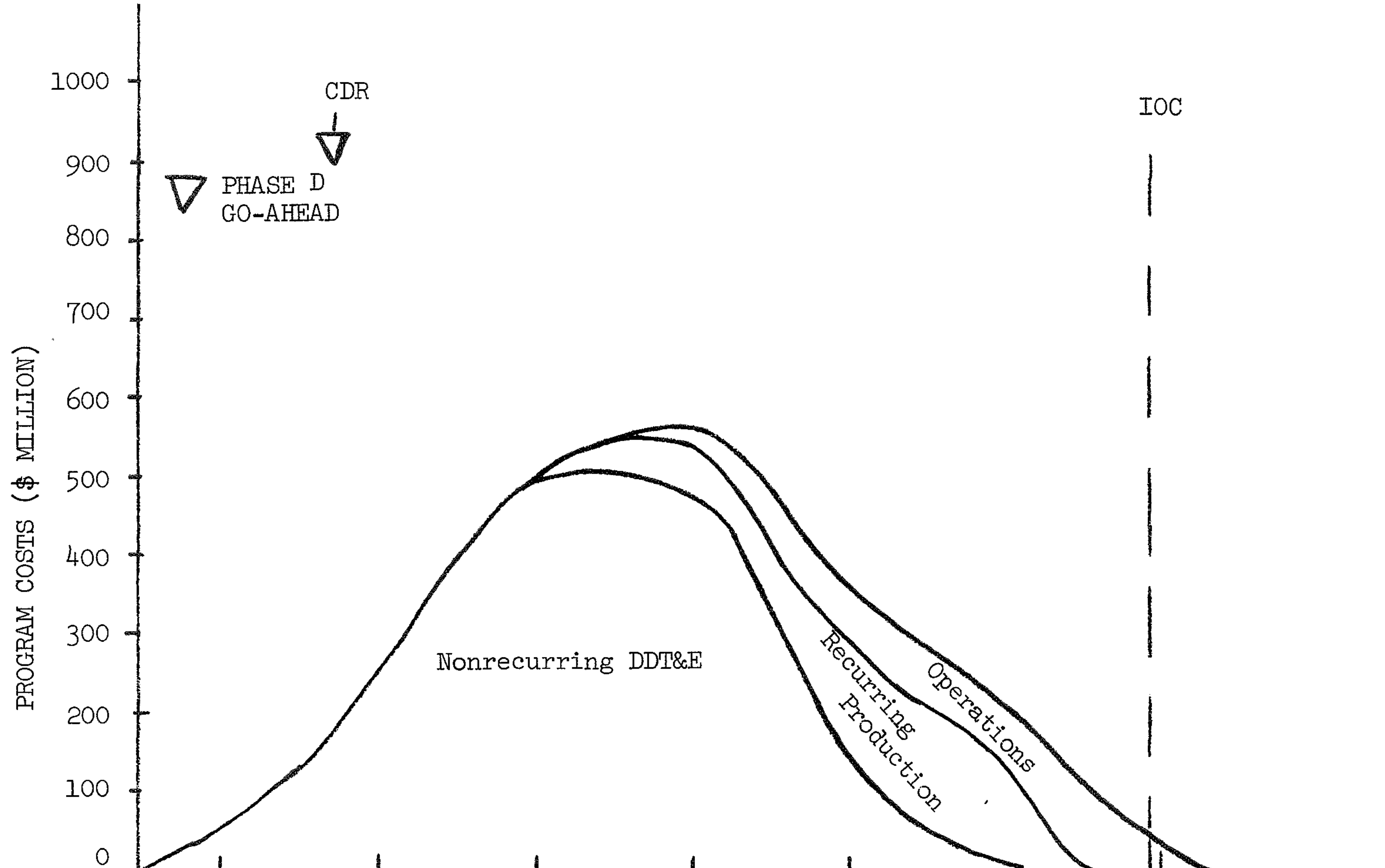
The total estimated cost, excluding contractor fee, for the representative OLS project element (WBS level 3) is summarized in Table 3-7 and the funding by GFY is displayed yearly on Figures 3-13 and 3-14. Table 3-6 also identifies cost to the system level (WBS level 4) in the nonrecurring and recurring cost categories.

3.5.4 Detail Cost Estimates

The detail cost and schedule data for the representative OLS is presented on NASA DATA Forms A, C, and D. A brief description of the form precedes each set of data.

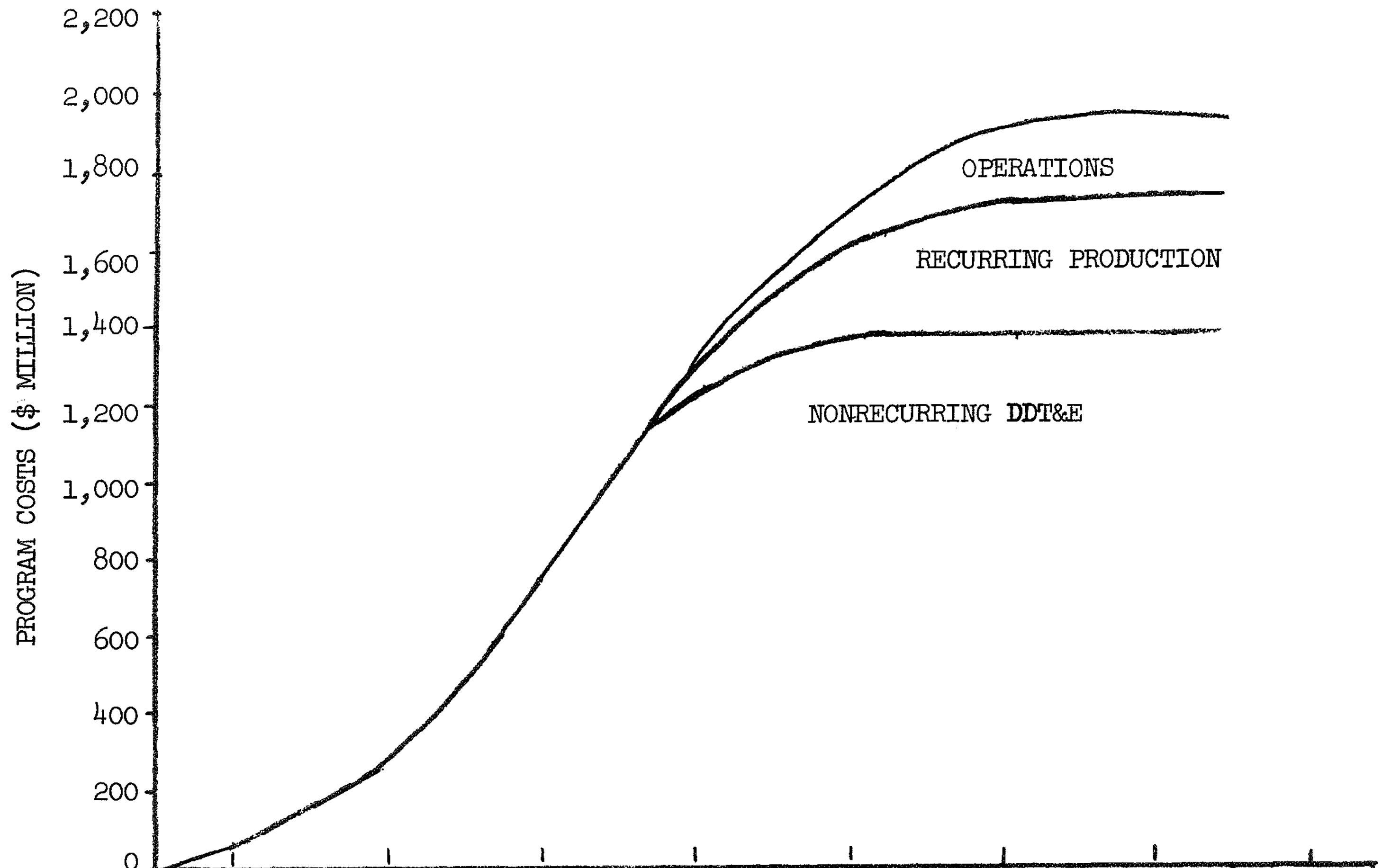
Table 3-7. Cost Summary for Representative OLS

Element	Nonrecurring DDT & E (Millions)	Recurring First Unit (Millions)
Core module	$ 472.0	$ 213.3
Experiment module	23.2	9.2
Power module	62.5	77.4
Subtotal	557.7	299.9
Major test hardware	438.4	-
Subtotal	996.1	299.9
Ground support equipment	154.4	5.8
Training equipment	24.9	-
Facilities	86.7	-
System support (system engineering)	66.7	9.3
Program management	47.8	6.9
Operations support (through launch)	-	14.9
Spares (initial flight)	-	11.0
Estimated cost (less fee)	$1,376.6	$ 347.8
Operations Support		
Launch through IOC (6 months)		22.3
Spares and replacements (10-year operations)		180.0
Total estimated cost (less fee)	$1,376.6	$ 550.1



GFY	1978	1979	1980	1981	1982	1983	1984	Total
DDT&E	45.2	235.9	481.7	475.9	135.7	2.2		1376.6
Production			3.9	61.9	149.1	132.9		347.8
Operations				19.2	74.8	74.4	33.9	202.3
Total	45.2	235.9	485.6	557.0	359.6	209.5	33.9	1926.7

Figure 3-13. Representative Orbiting Lunar Station GFY Funding Schedule



GFY	1978	1979	1980	1981	1982	1983	1984	
DDT&E	45.2	281.1	762.8	1238.7	1374.4	1376.6	1376.6	
Production			3.9	65.8	214.9	347.8	347.8	
Operations				19.2	94.0	168.4	202.3	
Total	45.2	281.1	766.7	1323.7	1683.3	1892.8	1926.7	

Figure 3-14. Representative Orbiting Lunar Station Cumulative GFY Funding Schedule

Data Form A

Data Form A outlines the total program cost estimate in millions of dollars by WBS items, the time phasing recommended to spread the costs for funding purposes, and a learning index to derive unit costs for recurring items. Separate cost estimates are presented for the design and development activity (nonrecurring costs) and the production and operations activities (recurring costs).

All data necessary to produce the funding schedule - Data Form D, are displayed on Data Form A. An explanation of these requirements is outlined in the following paragraphs.

Learning Index - A numerical index of a learning rate to be applied to the first unit cost of an item to obtain unit costs estimates for subsequent productions. If multiple items are to be produced and no learning index is given, it can be assumed all items are produced at the same cost.

WBS Level - The appropriate level of the item of cost as shown on the WBS.

Number of Units - The quantity of items to be produced.

T_d - The development time (months) or the production time (months) required to design and develop or produce the item. T_d is the duration of cost accrual.

T_s - The lead time (months) measured from the start of cost accrual for the item to the launch milestone.

Spread Function - An index number representing a cost distribution curve which the contractor recommends for the time-phasing of costs over the interval T_d; this index number is shown as 50-percent time at 50-percent cost, etc.

DATE ______
PAGE 1 OF 1

COST ESTIMATE DATA FORM A

x NON-RECURRING (DDT & E)
__ RECURRING (PRODUCTION)
__ RECURRING (OPERATIONS)

WBS Level	WBS IDENT. NUMBER a	WBS ITEM NAME b	WBS ITEM COST c	No. of Units d	Refer. Unit e	Learn Index f	T_d g	T_s h	SPREAD FUNC. i	MILESTONE DATE j
3	1XX-00-00-00-00	OLS Project Element	1,376.6	N/A	N/A	N/A	68	68		6-1-83
4	1XX-01-00-00-00	Core Module	472.0				51	68	40/60	6-1-83
4	1XX-02-00-00-00	Experiment Module	23.2				51	68	40/60	6-1-83
4	1XX-03-00-00-00	Power Module	62.5				51	68	40/60	6-1-83
4	1XX-04-00-00-00	Test Hardware	438.4				41	51	40/60	6-1-83
4	1XX-07-00-00-00	Ground Support Equipment	154.4				35	68	40/60	6-1-83
4	1XX-08-00-00-00	Training Equipment	24.9				50	68	40/60	6-1-83
4	1XX-06-00-00-00	Facilities	86.7				58	68	60/40	6-1-83
4	1XX-09-00-00-00	Systems Support (Sys. Engr.)	66.7				51	68	40/60	6-1-83
4	1XX-10-00-00-00	Program Management	47.8				51	68	40/60	6-1-83

DATE ______
PAGE 1 OF 1

COST ESTIMATE DATA FORM A

___ NON-RECURRING (DDT & E)
_X_ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)

WBS Level	WBS IDENT. NUMBER a	WBS ITEM NAME b	WBS ITEM COST c	No. of Units d	Refer. Unit e	Learn Index f	T_d g	T_s h	SPREAD FUNC. i	MILESTONE DATE j
3	1XX-00-00-00-00	OLS Project Element	347.8				41	41		6-1-83
4	1XX-01-00-00-00	Core Module	213.3	1	1	90	38	41	40/60	6-1-83
4	1XX-02-00-00-00	Experiment Module	9.2	1	1	90	23	26	40/60	6-1-83
4	1XX-03-00-00-00	Power Module	77.4	1	1	90	18	21	40/60	6-1-83
4	1XX-07-00-00-00	Sustaining GSE	5.8				10	10	50/50	6-1-83
4	1XX-09-00-00-00	Systems Support (Sys. Engr.)	9.3				17	17	40/60	6-1-83
4	1XX-11-00-00-00	Spares (Initial Flight)	11.0				41	43	40/60	6-1-83
4	1XX-10-00-00-00	Program Management	6.9				17	17	40/60	6-1-83
4	1XX-05-00-00-00	Pre-Mission Operations	14.9				4	4	40/60	6-1-83

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COST ESTIMATE DATA FORM A

___ NON-RECURRING (DDT & E)
___ RECURRING (PRODUCTION)
_X_ RECURRING (OPERATIONS)

WBS Level	WBS IDENT. NUMBER a	WBS ITEM NAME b	WBS ITEM COST c	No. of Units d	Refer. Unit e	Learn Index f	T_d g	T_s h	SPREAD FUNC. i	MILESTONE DATE j
3	1XX-00-00-00-00	OLS Project Element	202.3	N/A	N/A	N/A	6	6		12-1-83
4	1XX-05-00-00-00	Mission Operations Support	22.3				6	6	50/50	12-1-83
4	1XX-11-00-00-00	Spares (Operational)	180.0				47	49	40/60	12-1-83

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Data Form C

Technical Data Form C presents the technical, physical, and mission characteristics which may have a significant effect on the cost of an item.

The technical characteristics include sizing parameters; i.e., total impulse, weight, kwh, volume, etc.; performance parameters; minimum attitude change rates, I_{sp}, etc.; complexity parameters; i.e., number of restarts, number of attitude changes, etc.; reliability parameters; i.e., mission duration, maximum operating distance, etc.

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-00-00-00-00	Space Station Project	3	10 years 60 nautical miles 90 degrees 98.3 feet 104,305 pounds	Mission Duration Lunar Orbit Orbit inclination Overall station length Total dry weight*
1XX-01-00-00-00	Core Module System	4	8 man 85,155 pounds 27 feet 60.8 feet 4 2290 square feet 6 20,000 cubic feet 20 KW 6 months	Crew Size Dry weight Station diameter Station length Habitable decks Floor area Docking ports Shirtsleeve volume Nominal power Independent operation time period
1XX-01-01-00-00	Structure Subsystem	5	10 years - without replacement or extensive reconditioning of primary structure 27 feet 60.8 feet Toroidal Flat 2 Welded skin-stringer	Structural Life Diameter Length End bulkheads Pressure bulkhead Pressure isolation area volumes Cylindrical walls Design Ultimate Factors

*Excluding experiment module scientific equipment

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			2.0	Manned Operations
			1.5	Unmanned Operations
				Design Yield Factors
			1.50	Manned Operations
			1.20	Unmanned Operations
			Aluminum Alloy	Primary structural material
			Aluminum Alloy	Secondary structural material
			14.7 psia	Internal pressure - design limit
			28,300 pounds	Weight
			38,000 pounds	Axial thrust load at X-Axis docking ports
			690 pounds	Insulation
1XX-01-02-00-00	Environmental Protection Subsystem	5		Micrometeoroid Protection
			0.9 for 10 years	Probability of no penetration of crew/subsystem components
			4470 pounds	Weight
				Radiation Protection
			25 REM/year	Blood forming organs
			3000 pounds	Dry weight
1XX-01-03-00-00	Electrical Power Subsystem	5		Auxiliary Power Source -
				Non-Regenerative Fuel Cells
			4 KW for 30 days	Emergency
			10 KW for 3 days	Solar Flares
			15.2 KW for 3.5 hours	Eclipses
			2 KW for 5 days	Premanning
			120/208 vac, 3Ø, 400 Hz, 56 vdc	Power Distribution
			215 cubic feet	Gross volume
			5445 pounds	Weight

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-01-04-00-00	ECLSS	5	11,200 Btu/day/man	Metabolic load
			1.84 lb/man/day	O_2
			5.0 mm Hg nominal	CO_2 concentration
				Temperature selectivity
			65-75 degrees F.	All areas
			40 feet/minute	Ventilation rate
			17.42 pounds/man/day	Potable water usage
			12.01 pounds/man/day	Wash water usage
			22.4 pounds/day (N_2/O_2)	Atmosphere Leakage Makeup
				Pressure Control
			14.7 psia	Maximum
			10 psia	Minimum
				Thermal Protection
			90K/80K Btu/hour	Heat load
			2000 square feet	Radiator area
			760 pounds	Weight
			26.4 pounds/day	Trash Disposal (excluding feces)
				Food Management
			66 cubic feet	Frozen food storage
			8 pounds/30 min.	Food preparation
			8-12 cubic feet	Refrigerator
				Experiment Support
			35 pounds/day	Water recovery
			30 pounds/month	Trash
			4000 watts (maximum)	Thermal control
			14,920 pounds	Dry weight for 8 man/180 day

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-01-05-00-00	Docking Provisions	5	4	Passive Ring Assembly
			2	Active Ring/Cone Assembly
			4	Active/active adapter
				Precontact velocity
			0.5 fps	Axial
			0.3 fps	Radial
			0.5 degrees/second	Angular
				Alignment
			±5 inches	Radial
			±4 degrees	Angular
			±4 degrees	Rotational
			5360 slugs	Capture mass
			2480 pounds	Weight
1X-01-06-00-00	Information Subsystem	5		Internal Comm/Distribution
			4 KHz each	Voice - up to 90 channels
			4 KHz each	Intercom - up to 7 channels
			4.5 MHz each	CCTV - up to 7 channels
			10 KHz each	Entertain - up to 3 channels
			1 Mbs each	Digital data, redundant 2 channels
				External Comm.
			6.5 MHz composite	To Earth surface, direct to MSFN 2 way color TV, 2 way voice, 2 way data
			6.5 MHz composite	To Lunar surface via lunar satellite or direct 2 way color TV, 2 way data, 2 way voice

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			6.5 MHz composite	To CLS: 2 way voice, 2 way data, 2 way ranging
			Experiment unique	To DET modules; 2 way video, 2 way data, 2 way ranging
				Displays
			525 TV line, 9 inch x 9 inch	Universal multiformat (color CRT)
			15 lines, 50 characters	Discrete alphanumeric (light-emitting diode)
			6 digit with decimal	Discrete decimal (digital voltmeter)
			Monitor/Alarm	Discrete event (lights)
			600 lines per minute	Hard-copy test (printer)
				Hard-copy viewer (microfilm)
				Omni Antennas
			8	Number
			6 inch flush mount	Diameter
			8 pounds	Weight
				High Gain Antenna
			4	Body mounted arrays
			3	Aft mounted arrays
			1	Manually deployed 5 feet diameter sphere
			335 pounds	Weight
				Data Processor
			1×10^7 "Equiv Add" per second	Computation rate
			2.5×10^5 words (40 bits each)	Operating memory capacity

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			3.3×10^6 words	Mass memory capacity
			Up to 5×10^6 bits per second	1/0 unit transfer rate
			Up to 64 RACU's	1/0 port capacity
			1×10^6 bits per second	Archive capacity
				Other storage requirements
			25 hours	Television (4.5 MHz)
			48 hours	Entertainment (10 KHz)
			2000 hours	Voice (4 KHz)
			3×10^6 pages	Text (microfilm)
			6380 pounds	On orbit weight (station & experiments)
			338 cubic feet	On orbit volume
1XX-01-07-00-00	Guidance & Control Subsystem	5		State vector estimation (1 sigma)
			±330 feet	Altitude
			±950 feet	In-track
			±490 feet	Cross track
			±0.4% (25 fps)	Velocity
				Attitude Control
			±5 degrees	Premanning
			±1 degree	Manning
			±2.5 nautical miles altitude	Station orbit maintenance
			2255 pounds	Initial on-orbit weight
			185.5 cubic feet	Initial on-orbit volume
			588 watts	Electrical power - average
			8100 feet/pound/second	Momentum storage (CMGs)
				Total

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-01-08-00	Reaction Control Subsystem	5		Zero g - 180 days
			2,049,000 pounds-second	Orbit make-up, total impulse
			153,000 pounds-second	Attitude hold, total impulse
			12,000 pounds-second	Attitude maneuver, total impulse
			82,000 pounds-second	Emergency, total impulse
			3963 pounds	Propellant weight
				Total cryogenic storage (includes ECLSS and EPS)
			6823 pounds	Oxygen
			1645 pounds	Hydrogen
			3551 pounds	Nitrogen
			7811 pounds	Subsatellite provisions - N_2H_4 Storage
			10 pounds	Engine thrust
			Four engine quads/four engines per quad	Engine assembly
				Cryogenic storage
			2	Oxygen tanks
			8	Hydrogen tanks
			2	Nitrogen tanks
			8625 pounds	Weight, dry
1XX-01-09-00-00	Crew Habitability	5		Crew items for 8 men/180 days
			2390 pounds	Personnel equipment
			1080 pounds	Crew station control & panels

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PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-01-10-00-00	Laboratory Provisions	5	5120 pounds 3850 cubic feet 4 KW 7 KW 6 KW 240 square feet	Weight Volume Power* Normal continuous Peak - 1 minute Maximum - 1 hour Floor area
		*NOTE:	The power shown may be applied to experiments in the Core Module only, to experiments in the Experiments Module only, or split between experiments in both the Core Module and in the Experiments Module, however, the total power for experiments will never exceed the values shown.	
1XX-02-00-00-00	Experiments Module	4	176.7 square feet 1 2 5 feet diameter 14 feet diameter 7850 pounds 15 feet 24 feet 4240 cubic feet 3 110 square feet	Floor area Airlock Hatches Side access End access Initial orbital weight Module diameter Module length Shirtsleeve volume Docking ports Sensor mounting area
1XX-02-01-00-00	Structure Subsystem	5	10 years - without replacement or extensive reconditioning of primary structure	Structural Life

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			15 feet	Diameter
			24 feet	Length
			Flat	End bulkheads
			Welded skin-stringer	Cylindrical walls
				Design Ultimate Factors
			2.0	Manned Operations
			1.5	Unmanned Operations
				Design Yield Factors
			1.50	Manned Operations
			1.20	Unmanned Operations
			Aluminum Alloy	Primary structural material
			Aluminum Alloy	Secondary structural material
			14.7 psi	Internal pressure - design limit
			4210 pounds	Weight
			38,000 pounds	Axial thrust load at docking ports
			720 pounds	Spares - All Subsystems
1XX-02-02-00-00	Environmental Protection Subsystem	5	57 degrees F.	Dew point
			0.9 for 10 years	Probability of no micrometeoroid penetration of crew/subsystem components
			57 degrees F.	Minimum internal surface temperature
			850 pounds	Dry weight

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-02-03-00-00	Electrical Power Subsystem	5		Normal operations power*
			4 KW	Average
			7 KW for 1 minute	Peak
			6 KW for 1 hour	Maximum
			840 pounds	Weight
		*NOTE:	The power shown may be applied to experiments in the Core Module only, to experiments in the Experiments Module only, or split between experiments in both the Core Module and the Experiments Module, however, the total power for experiments will never exceed the values shown.	
1XX-02-04-00-00	EC/LSS		11,900 Btu/day/man	Metabolic load
			1.84 pounds/man/day	O_2
			5 mm Hg nominal	CO_2 concentration
				Temperature control
			65 - 75 degrees F.	Integral experiments
			60 - 75 degrees F.	All other areas
			1000 watts	Sensible heal load for integral experiments
				Pressure control
			14.7 psia	Maximum
			10 psia	Minimum
				Humidity control
			8 to 12 mm Hg	H_2O partial pressure
			100 pounds	Dry weight

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-02-05-00-00	Docking Provisions	5	2	Passive Ring Assemblies
			1	Subsatellite retrieval mechanism
				Precontact velocity
			0.5 fps	Axial
			0.3 fps	Radial
			0.5 degrees/second	Angular
				Alignment
			±5 inches	Radial
			±4 degrees	Angular
			±4 degrees	Rotational
			5360 slugs	Capture mass
			1130 pounds	Weight
1XX-03-00-00-00	Power Module	4	37.5 feet	Length
			7 feet	Diameter
			11,300 pounds	Launch weight
			1,440 cubic feet	Pressurizable volume
			2	Docking ports
1XX-03-01-00-00	Structure Subsystem	5	10 years - without replacement or extensive reconditioning or primary structure	Structural Life
			7 feet	Diameter
			37.5 feet	Length
			Flat	End bulkheads
			Welded skin-stringer	Cylindrical walls
				Design Ultimate Factors
			2.0	Manned Operations
			1.5	Unmanned Operations

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			 1.50 1.20 Aluminum Alloy Aluminum Alloy 14.7 psia 1540 pounds 38,000 pounds	Design Yield Factors Manned Operations Unmanned Operations Primary structural material Secondary structural material Internal pressure - design limit Weight Axial thrust load at docking ports
1XX-03-02-00-00	Environmental Protection Subsystem	5	117 pounds 0.9 for 10 years 450 pounds	Insulation Micrometeoroid Protection Probability of no penetration of crew/subsystem components Weight
1XX-03-03-00-00	Electrical Power Subsystem	5	 20 KW 28 KW Solar Array (10 K square feet) 120/208 vac, 3Ø, 400 Hz, 56 vdc 4720 pounds Regenerative fuel cells 721 pounds 215 cubic feet 7440 pounds	Normal Operations Power Average Peak Primary and secondary power source Power Distribution Weight Primary and secondary power energy storage Weight Gross volume (excluding solar array Total weight

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-03-04-00-00	*EC/LSS	5	11,900 Btu/day/man	Metabolic load
			1.84 pound/man/day	O_2
			5 mm nominal	CO_2 concentration
			60 - 75 degrees F.	Temperature selectivity
				Pressure control
			14.7 psia	Maximum
			0 psia	Minimum
				Thermal protection
			19.8K/73.5K Btu/hour	Heat load
			500 square feet	Radiator area
			470 pounds	Weight
			1080 pounds	Dry weight
1XX-03-05-00-00	Docking Provisions	5	2	Passive Ring Assembly
				Precontact velocity
			0.5 fps	Axial
			0.3 fps	Radial
			0.5 degrees/second	Angular
				Alignment
			±5 inches	Radial
			±4 degrees	Angular
			±4 degrees	Rotational
			5360 slugs	Capture mass
			560 pounds	Weight

*NOTE: The interior of the Power Module is normally at ambient pressure. However, during periodic servicing and emergency conditions, the interior will be pressurized and a shirtsleeve environment will be provided.

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-03-06-00-00	Information Management Subsystem	5	230 pounds	Internal Data Links Weight

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Data Form D

Data Form D presents an estimate of the resources by government fiscal year required to accomplish subsequent phases of the OLS program. Separate funding schedules are included for design and development (nonrecurring), production (recurring), and operations (recurring).

These schedules present the summarization of cost estimates at level 4 of the WBS items into the project level. To accomplish this, the WBS cost estimate at level 4 is time-phased by fiscal year against the proposed development and production plans by using the appropriate spreading function, and the results summarized to produce the funding schedules. Details are contained on cost form A. When the schedule of a lower level item is flexible, the schedule has been adjusted to smooth or minimize the peak funding of the project. Funding schedules for major program items are presented separately for the nonrecurring and recurring costs.

COST ESTIMATE DATA FORM D

DATE ____
PAGE 1 OF 1

X NON-RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)

WBS Level	WBS IDENT. NUMBER a	WBS ITEM NAME b	WBS ITEM COST c	GFY '78	GFY '79	GFY '80	GFY '81	GFY '82	GFY '83	GFY '84
3	1XX-00-00-00-00	OLS Project Element	1,376.6	45.2	235.9	481.7	475.9	135.7	2.2	
4	1XX-01-00-00-00	Core Module	472.0	19.6	95.4	155.0	143.7	58.3		
4	1XX-02-00-00-00	Experiment Module	23.2	1.0	4.7	7.6	7.0	2.9		
4	1XX-03-00-00-00	Power Module	62.5	2.6	12.6	20.5	19.0	7.8		
4	1XX-04-00-00-00	Test Hardware	438.4		11.0	164.3	224.9	38.2		
4	1XX-07-00-00-00	Ground Support	154.4	8.7	64.2	63.8	17.7			
4	1XX-08-00-00-00	Training Equipment	24.9	1.0	5.0	8.2	7.6	3.1		
4	1XX-06-00-00-00	Facilities	86.7	7.5	19.8	24.7	21.1	11.4	2.2	
4	1XX-09-00-00-00	Systems Support (Sys. Engr.)	66.7	2.8	13.5	21.9	20.3	8.2		
4	1XX-10-00-00-00	Program Manage-	47.8	2.0	9.7	15.7	14.6	5.8		

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___ NON-RECURRING (DDT&E)
_X_ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)

WBS Level	WBS IDENT. NUMBER a	WBS ITEM NAME b	WBS ITEM COST c	GFY '78	GFY '79	GFY '80	GFY '81	GFY '82	GFY '83	GFY '84
3	1XX-00-00-00-00	OLS Project Element	347.8			3.9	61.9	149.1	132.9	
4	1XX-01-00-00-00	Core Module	213.3			3.6	57.4	101.2	51.1	
4	1XX-02-00-00-00	Experiment Module	9.2				.4	4.9	3.9	
4	1XX-03-00-00-00	Power Module	77.4					30.9	46.5	
4	1XX-07-00-00-00	Sustaining GSE	5.8						5.8	
4	1XX-09-00-00-00	Systems Support (Sys. Engr.)	9.3					3.7	5.6	
4	1XX-11-00-00-00	Spares (Initial Flight)	11.0			.3	4.1	5.6	1.0	
4	1XX-10-00-00-00	Program Management	6.9					2.8	4.1	
4	1XX-05-00-00-00	Pre-Mission Operations	14.9						14.9	

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COST ESTIMATE DATA FORM D

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___ NON-RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
_X_ RECURRING (OPERATIONS)

WBS Level	WBS IDENT. NUMBER a	WBS ITEM NAME b	WBS ITEM COST c	GFY '78	GFY '79	GFY '80	GFY '81	GFY '82	GFY '83	GFY '84
3	1XX-00-00-00-00	OLS Project Element	202.3				19.2	74.8	74.4	33.9
4	1XX-05-00-00-00	Mission operations support	22.3							22.3
4	1XX-11-00-00-00	Spares (operational)	180.0				19.2	74.8	74.4	11.6

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4.0 DERIVATIVE OLS COST AND SCHEDULE DATA

This section presents cost and development schedule data for the derivative OLS configuration defined in Volume V of this report. The cost and development schedule data include:

1. Hardware Utilization List
2. Test Requirements
3. Program Development Schedule and Plan
4. Work Breakdown Structure
5. Program Cost Estimates

Program cost data include cost methodology, cost summaries with schedules, detail cost and technical characteristics. The cost data presented in this section was prepared in accordance with the NASA instructions in the Data Requirements Description for DRL line item 1 as applicable to this Phase A study. Included are:

1. Total Program Cost Estimate Data by Work Breakdown Structure (WBS) Items (Data Form A)

2. Technical Characteristics Data (Data Form C)

3. Total Program Funding Schedules (Data Form D)

A summary program development schedule for the derivative OLS is shown in Figure 4-1. This schedule shows the proposed phasing, development activities, and major milestones involved in the fabrication, assembly, and test of the derivative OLS. Major program phasing depicted on the schedule includes a 12-month Phase B definition study to commence on February 1, 1975, followed by a 6-month customer evaluation and review period. A 12-month Phase C design study is scheduled to start August 1, 1976 and upon the completion of Phase C, the program will proceed directly into Phase D development/operations. A major program assumption used in the preparation of the preliminary Program Development Schedule is that the first translunar flight will take place on June 1, 1983. Tne In Operational Condition (IOC) date is scheduled six months later on December 1, 1983.

The test program to support the derivative OLS consists of major ground structural testing of four structural test articles which covers a time span of approximately 19 months. Upon completion of the structural testing, the structural test modules will be used as part of the interface test article. Manufacturing time spans for the different test and flight articles vary in length depending on the amount of structure to be fabricated and assembled, and systems to be installed. A detailed Program Development Schedule for the derivative OLS which includes activities in Phases B, C and D is presented in this section.

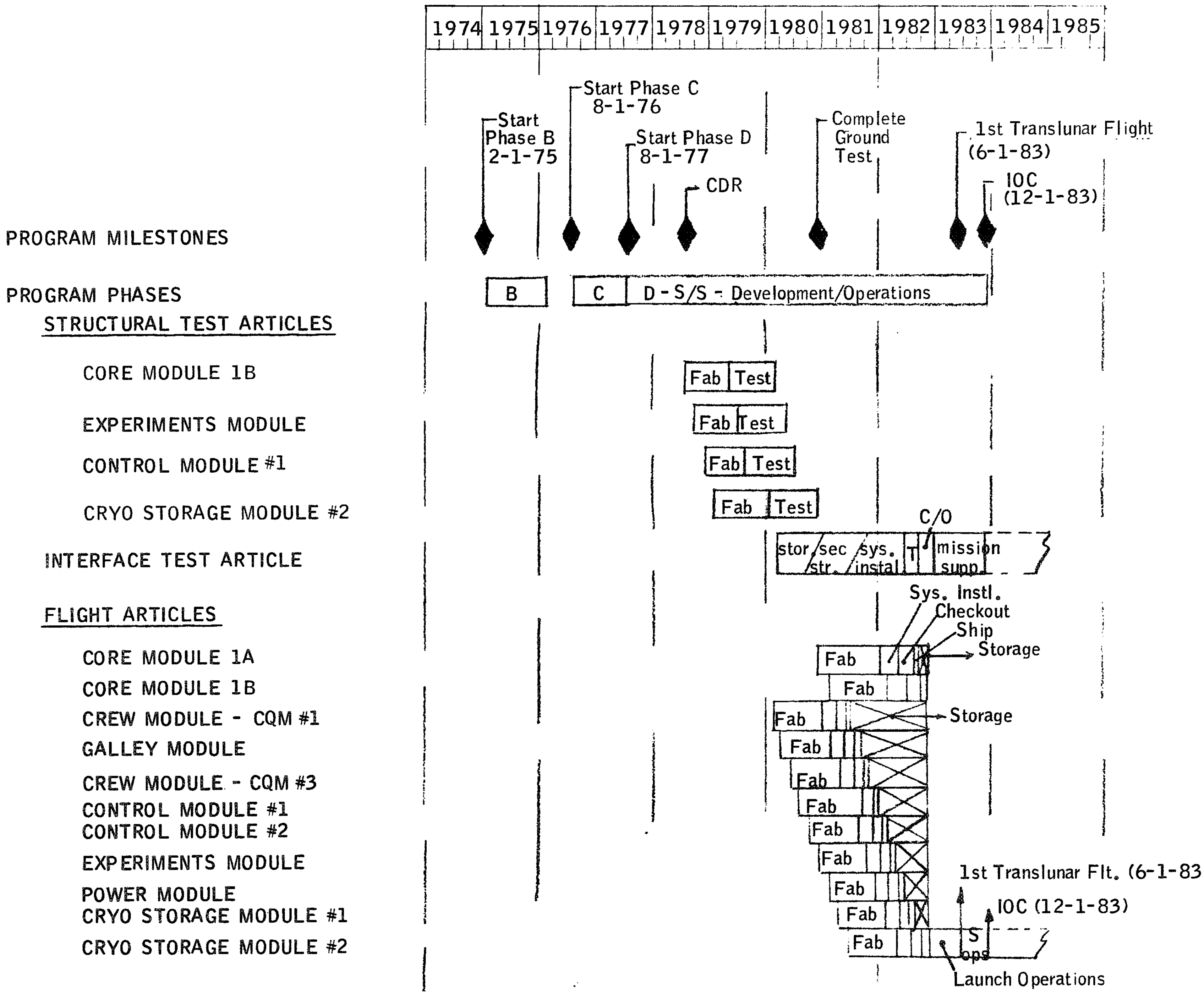


Figure 4-1. Derivative Orbiting Lunar Station - Preliminary Program Development Summary Schedule

4.1 HARDWARE TREE

The preliminary hardware tree shown in Figure 4-2 presents a structural breakdown of the derivative OLS baseline configuration defined in Volume V of this report. The hardware tree identifies the modules (systems), subsystems and major components of the derivative OLS. It provides a visual presentation of the hardware requirements and the relationships between them.

The hardware tree served as a key tool in the identification and preparation of development requirements, major test articles, and the Program Development Schedule. It was used to provide assurance that all subsystems and major components were considered for development analysis and served as a basis for broad program planning, schedule preparation, and cost estimating.

Upon completion of the identification of development requirements, the hardware tree is updated to a Hardware Utilization List (HUL) which includes all units that are to be fabricated.

4.2 DEVELOPMENT TEST REQUIREMENTS

The following paragraphs describe a concept for development, qualification, and acceptance testing of the derivative OLS. This configuration of the OLS is derived from the earth orbiting Modular Space Station (MSS); therefore, much of the test approach, logic and data derived in the MSS study will be directly applicable to the derivative OLS.

The test concept presented utilizes the resources of the MSS to resolve derivative OLS development issues prior to OLS Phase C design and is designed to make maximum use of MSS data obtained in the individual subsystem disciplines. Additional tests proposed will include structural and integrated tests utilizing interface test articles.

4.2.1 Test Philosophy

The detailed test philosophy proposed for representative OLS development, presented in paragraph 3.2.1 is equally applicable to the derivative OLS. As for the representative OLS, a Development Requirements Analysis (DRA) approach is used in establishing an integrated test program plan for the derivative OLS. The DRA approach is the same as for the representative OLS illustrated in Figure 3-3. The resultant derivative OLS integrated test program concept is identical to that shown for the representative OLS in Figure 3-4.

This test approach is designed to provide assurance that the OLS can be successfully delivered to lunar orbit and is capable of achieving its mission objectives throughout its ten-year operational life. To provide this assurance, the test program begins in Phase B during preliminary design with identification of critical development issues--the majority of which will be resolved by MSS test programs. The remaining, unresolved development issues will be in the translunar delivery loads and subsystem integration/interface areas peculiar to the OLS.

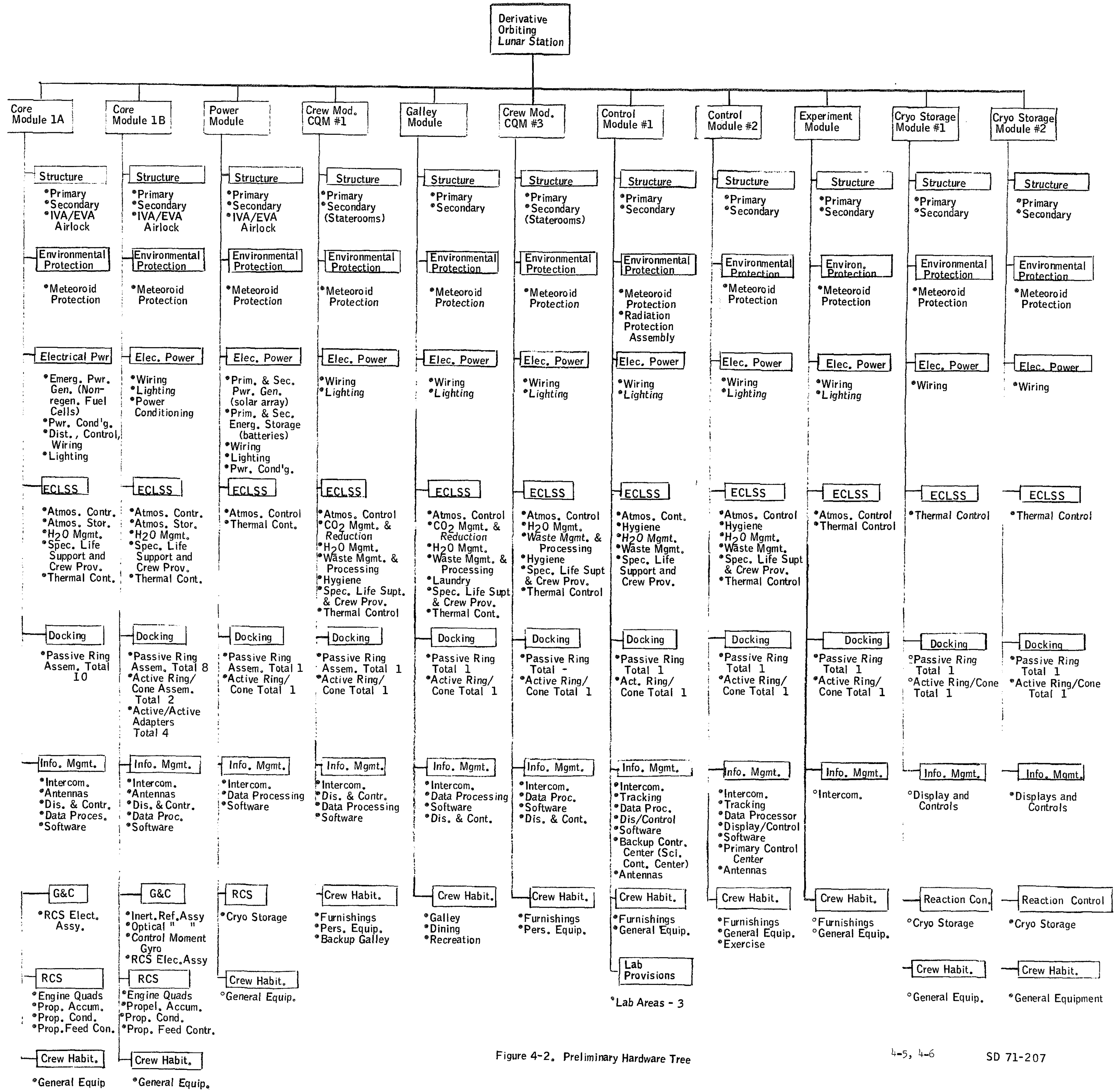


Figure 4-2. Preliminary Hardware Tree

4.2.2 Test Requirements

An integrated test program composed of development tests, qualification tests, and acceptance tests will be required to provide assurance that the derivative OLS can safely and successfully complete its mission objectives in lunar orbit.

Development Tests

A comparative analysis of the modules which make up the derivative OLS with their parent MSS modules indicates a need for soft mockups and structural test articles for certain derivative OLS modules. Soft mockups of the galley module, cryogenic storage module #2, experiments module, and control center module #1 are required. All other modules are quite similar to their baseline MSS modules. Structural test articles will be limited to core module 1B, experiments module, control center module #1, and the cryogenics storage module #2. The loads placed upon the structure of the core modules during lunar orbit delivery require significant modifications to the MSS design. Control center #1 contains the radiation protection shelter and is a major modification of its MSS module counterpart. The experiment and cryogenic storage modules are unique modules in the OLS configuration.

An interface test article is also required. It consists of an assemblage of the OLS modules (excluding solar arrays) which will have the capability of simulating functional interfaces with the OLS. Other than the four OLS structural test articles, the assemblage will consist of MSS interface test articles.

The major test articles and their subsystem complement are summarized in Table 4-1.

The long-life, high-reliability requirements of the OLS coupled with the limited production quantities, dictate the selection of proven materials, components, and techniques wherever possible. The majority of these selections will have been made during the preceding MSS development. The primary development testing requirements will be associated with unique OLS requirements.

Verification of compliance with performance requirements resulting from OLS deltas to the MSS configuration will be satisfied by analysis and/or development tests. In those cases requiring resolution by test, the procedures described in the following paragraphs, which is essentially the same as that for the representative OLS presented in Section 3.0, will apply.

The determination and verification of checkout and operational procedures will be a requirement of the subsystem development program. During development testing, the parameters which are most indicative of the performance capability of the subsystem and/or component being tested will be established. These data will be incorporated into a data bank for use in defining checkout procedures and resolving data anomalies during subsequent higher level assembly tests.

Table 4-1. Derivative Orbiting Lunar Station Development Test Articles

Primary Structure	Secondary Structure	RCS	Environ. Protection	EPS	ECLSS	ISS	G&C	Docking	Crew Habitability	Test Article
← Simulated Subsystems →										OLS mockup (wood)
										Galley module
										Cryo storage module #2
										Experiment module
										Control module #1
										Structural test article
1.0(F)	0.1(F)		0.4(P)		0.3(P)			0.2(P)		Core module #1B
1.0(F)	0.1(F)		0.4(P)		0.3(P)			0.2(P)		Cryo storage module #2
1.0(F)	0.1(F)		0.4(P)		0.3(P)			0.2(P)		Experiment module
1.0(F)	0.1(F)		0.4(P)		0.3(P)			0.2(P)		Control module #1
0.0[2]	0.5(F)	0.5(F)	0.5(F)	0.5(F)[1]	0.5(F)	0.5(F)	0.5(F)	0.5(F)	0.5(F)	Interface test article (Same modules as above

LEGEND:

S = Simulated
P = Prototype
F = Flight

NOTES:

1. Does not include solar arrays
2. Structures from structural test article

Delta maintenance concepts and procedures will be developed and verified on the MSS.

Structural testing will verify a satisfactory design margin for operational limits. Destructive testing of major structural test articles will be avoided to permit reuse of major structural test articles in subsequent test operations. Tests performed on major structural test articles will be performed at less than the conservative design factor (e.g., 1.5 times on primary structure).

All primary structure and structural interfaces between program elements will be statically and dynamically verified by test and/or analysis. Physical mating of all program elements will be verified by using the MSS tooling and/or fit-check fixtures. These same tools and fixtures will be used to verify the compatibility of subsequently launched elements with existing elements.

The orbiting MSS or its supporting ground facilities will be used to verify the initial OLS software. Capabilities and hardware interfaces subsequent to initial OLS launch will be verified on the interface test article.

Mission life test will be based upon the same criteria as the representative OLS; i.e., resupply considerations or schedule maintenance periods and multiples thereof, rather than on the total life expectancy of ten years. Assurance of component long life and reliable operation will be assisted by establishment of design requirements that consider off-the-shelf component history, performance derating, and MSS operational data. Life test criteria and analysis of failures will be the same as for the representative OLS (Figure 3-5 and Table 3-1 of Section 3.0).

Delta subsystem development testing from the MSS, which will include a teardown and inspection, will be performed for the derivative OLS. The degree of teardown and inspection will be defined for each subsystem during Phase B preliminary design. These data will be fed to the central data bank for application during subsequent malfunction investigations.

Qualification Tests

Qualification test philosophy, purpose, and procedures for the derivative OLS are identical to that for the representative OLS as presented in Section 3.0. A matrix, which is a part of the total launch assurance matrix, will be developed to identify specific tools and/or analyses required to assure confidence that OLS equipment is capable of meeting mission performance requirements.

Component and subassembly interfaces will be verified in subsystem qualification tests. Subsystem interfaces, including compatibility with the onboard checkout part of the Information Subsystem (ISS) are verified on the interface test article. Some of the MSS qualification testing will be applicable to the representative OLS; even more will be applicable to the derivative OLS configuration and should significantly reduce the cost of this phase of the OLS program.

Acceptance Testing

The objectives and procedures for acceptance testing of the derivative OLS are the same as for the representative OLS presented in Section 3.0. At each level of assembly, tests are conducted to insure conformance with configuration, quality and performance requirements to insure compatibility with interfacing hardware at the next level of assembly.

Acceptance testing at the subsystem level (installed in a program element) will include a demonstration of alternate/redundant modes of operation, together with the malfunction switching logic, by exercise of subroutines inherent to the onboard checkout capability of the ISS. Wherever possible, alternate/redundant path checkout capability, via malfunction simulation, will be an inherent subsystem checkout feature and will be accomplished without disturbing the flight configuration. This same philosophy will apply at the system level, primarily to verify all functional OLS interfaces and to assure that the onboard checkout capability will adequately status all modes of operation by means of appropriate subroutines.

Each subsystem test program will include subsystem acceptance tests before installation. Subsystem performance will be determined within the operational ranges expected in flight. Dynamic interfaces with other subsystems will be simulated to the extent practical with bench level equipment.

Electromagnetic compatibility (EMC) will be established at the design level and verified in the normal test and checkout sequence. Integrated tests in the development and acceptance cycle will verify that no electromagnetic interference (EMI) problems exist.

Acceptance testing at the modular level of all the OLS modules will begin with subsystems installations and conclude with the launch of the Earth Orbit Shuttle. Flow requirements for a typical OLS module are depicted in Figure 4-3.

Modular integrated tests will be accomplished utilizing the onboard flight ISS, the interface test articles, and portion of the MSS mission support vehicle.

Following the above verifications, the modules will be shipped to the Earth Orbit Shuttle (EOS) launch site. At the launch site, modules will be installed in the EOS cargo bay and launched into earth orbit. The modules will be assembled in earth orbit corresponding to their translunar flight configuration. A partially assembled OLS configuration defined in Volume V, is delivered on the first cislunar shuttle. A performance verification test will be conducted while this assemblage is in earth orbit.

4.2.3 Test Facility Requirements

The derivative OLS test program will require the use of several test facilities. The most significant ones are described briefly in the following paragraphs.

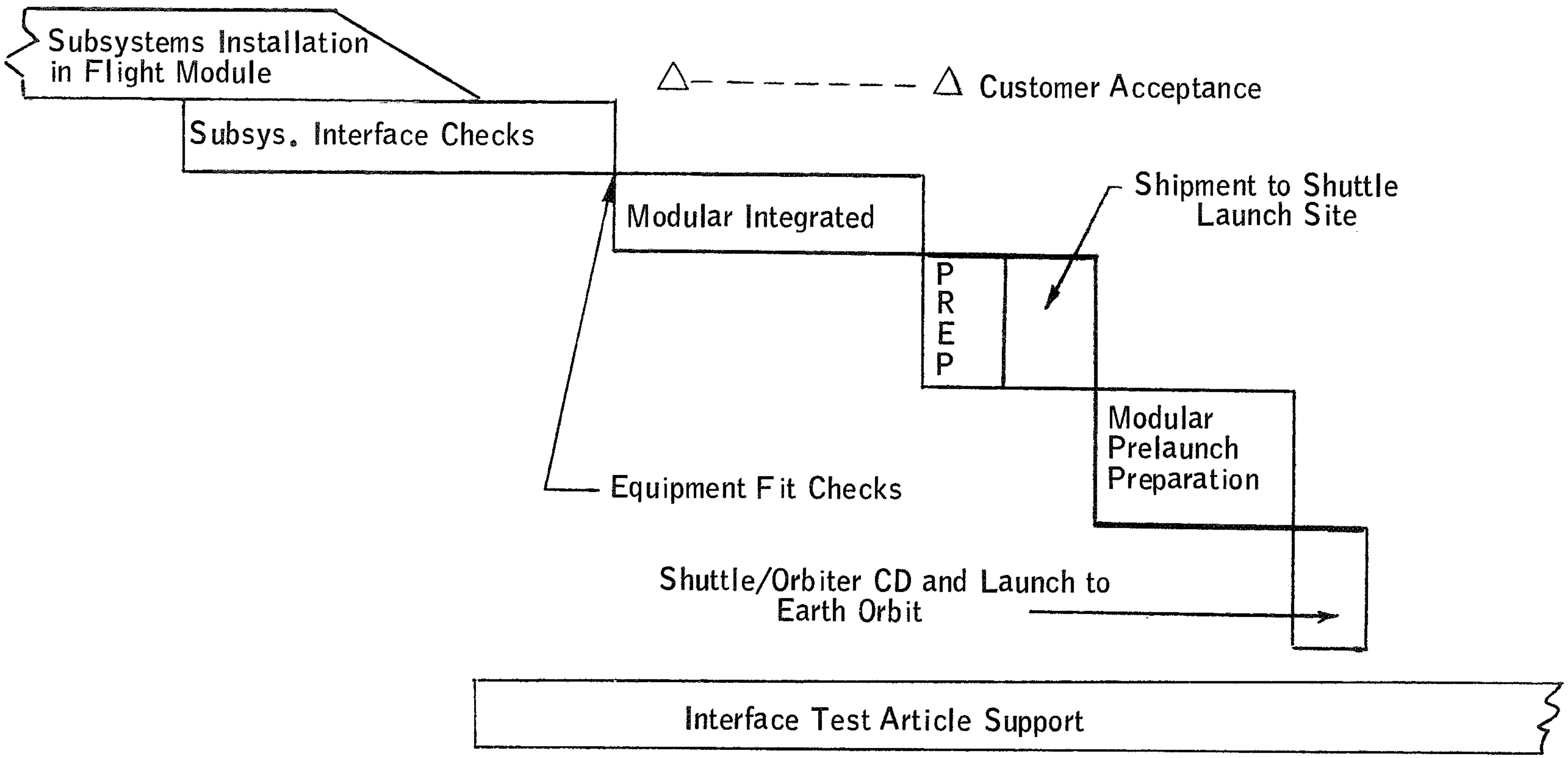


Figure 4-3. Typical OLS Modular Flow Requirements

A structural test facility will be required that will be large enough to accommodate three modules (core, cryo, experiment) along with the loading devices necessary to conduct a static structural test program. Requirements include both static loading at ambient temperatures and at elevated temperatures.

The schedule for fabrication and assembly of the OLS modules indicates that an acceptance test facility capable of accommodating at least five modules simultaneously is required.

The module interface tests and mission support functions will require a special facility. This facility must provide for multiple modules and their subsystems functionally interconnected. It is anticipated that maximum use of the MSS mission support vehicle facilities will be possible.

4.2.4 Hardware Utilization List

The Hardware Utilization List (HUL) for the derivative Orbiting Lunar Station is broken down into two categories, equivalent subsystem test hardware requirements, Table 4-2, and operational flight hardware requirements, Table 4-3.

A breakdown of the subsystems for the test hardware requirements consists of: primary structure, secondary structure, reaction control, environmental protection, electrical power, environmental control and life support, information management, guidance and control, docking, and crew habitability. Equivalent percentages of each of the above listed subsystems were determined for the test articles. These percentages along with the mockups and test articles required for the derivative OLS design verification, are shown in Table 4-2.

The operational flight hardware subsystem requirements for the derivative OLS are summarized in Table 4-3.

4.3 DETAILED DEVELOPMENT SCHEDULE

Derivative OLS manufacturing and test operations schedules discussed in the following paragraphs include a detailed Program Development Schedule, a Summary Schedule, and Manufacturing Schedules. These schedules include an integrated set of activities and milestones and reflect the requirements for test articles and mockups. One operational derivative OLS is shown on the schedules.

4.3.1 Manufacturing Schedules

A manufacturing flow plan for a typical module is shown in Figure 4-4. This plan shows the timespan, in months, required to fabricate, assemble, and check out a typical module of the type proposed for crew quarters, galley, control center, and cryogenic storage modules. The flow times shown are based on experience in the serial production of the Saturn S-II stage, which uses a similar method of construction for the main portion of the vehicle. Unique items, such as the docking port end bulkhead, have been subjected to a schedule analysis based upon in-house experience with high-energy forming,

Table 4-2. Derivative OLS Hardware Utilization List

	Primary Structure	Secondary Structure	RCS	ENPS	EPS	ECLSS	ISS	G&C	Docking	Crew Habitability
Core module 1B	1(F)	1(F)	1(F)	1(F)	1(F)	1(F)	1(F)	1(F)	1(F)	1(F)
Structural test	1(F)[2]	0.1(F)	-	0.4(F)	-	0.3(F)	-	-	0.2(F)	-
Interface test	-	0.5(F)	0.5(F)	0.5(F)	0.5(F)	0.5(F)	0.5(F)	0.5(F)	0.5(F)	0.5(F)
Cryo storage module #2	1(F)	1(F)	1(F)	1(F)[1]	1(F)	1(F)	1(F)	-	1(F)	1(F)
Mockup	1(S)	1(S)	1(S)	1(S)	1(S)	1(S)	1(S)	-	1(S)	-
Structural test	1(F)[2]	0.1(F)	0.5(P)[1]	0.4(P)	-	0.3(P)	-	-	0.2(P)	-
Interface test	-	0.5(F)	0.5(F)[1]	0.5(F)	0.5(F)	0.5(F)	0.5(F)	-	0.5(F)	0.5(F)
Galley module	1(F)	1(F)	-	1(F)	1(F)	1(F)	1(F)	-	1(F)	1(F)
Mockup	1(S)	1(S)	-	1(S)	1(S)	1(S)	1(S)	-	1(S)	1(S)
Experiment module	1(F)	1(F)	1(F)[3]	1(F)	1(F)	1(F)	1(F)	-	1(F)	1(F)
Mockup	1(S)	1(S)	1(S)	1(S)	1(S)	1(S)	1(S)	-	1(S)	1(S)
Structural test	1(F)[2]	0.1(F)	-	0.4(P)	-	0.3(P)	-	-	0.2(P)	-
Interface test	-	0.5(F)	0.5(F)	0.5(F)	0.5(F)	0.5(F)	0.5(F)	-	0.5(F)	0.5(F)
Control module #1	1(F)	1(F)	-	1(F)	1(F)	1(F)	1(F)	-	1(F)	1(F)
Mockup	1(S)	1(S)	-	1(S)	1(S)	1(S)	1(S)	-	1(S)	1(S)
Structural test	1(F)[2]	0.1(F)	-	0.4(P)	-	0.3(P)	-	-	0.2(P)	-
Interface test	-	0.5(F)	-	0.5(F)	0.5(F)	0.5(F)	0.5(F)	-	0.5(F)	0.5(F)

LEGEND:

S = Simulated
P = Prototype
F = Flight

NOTES:

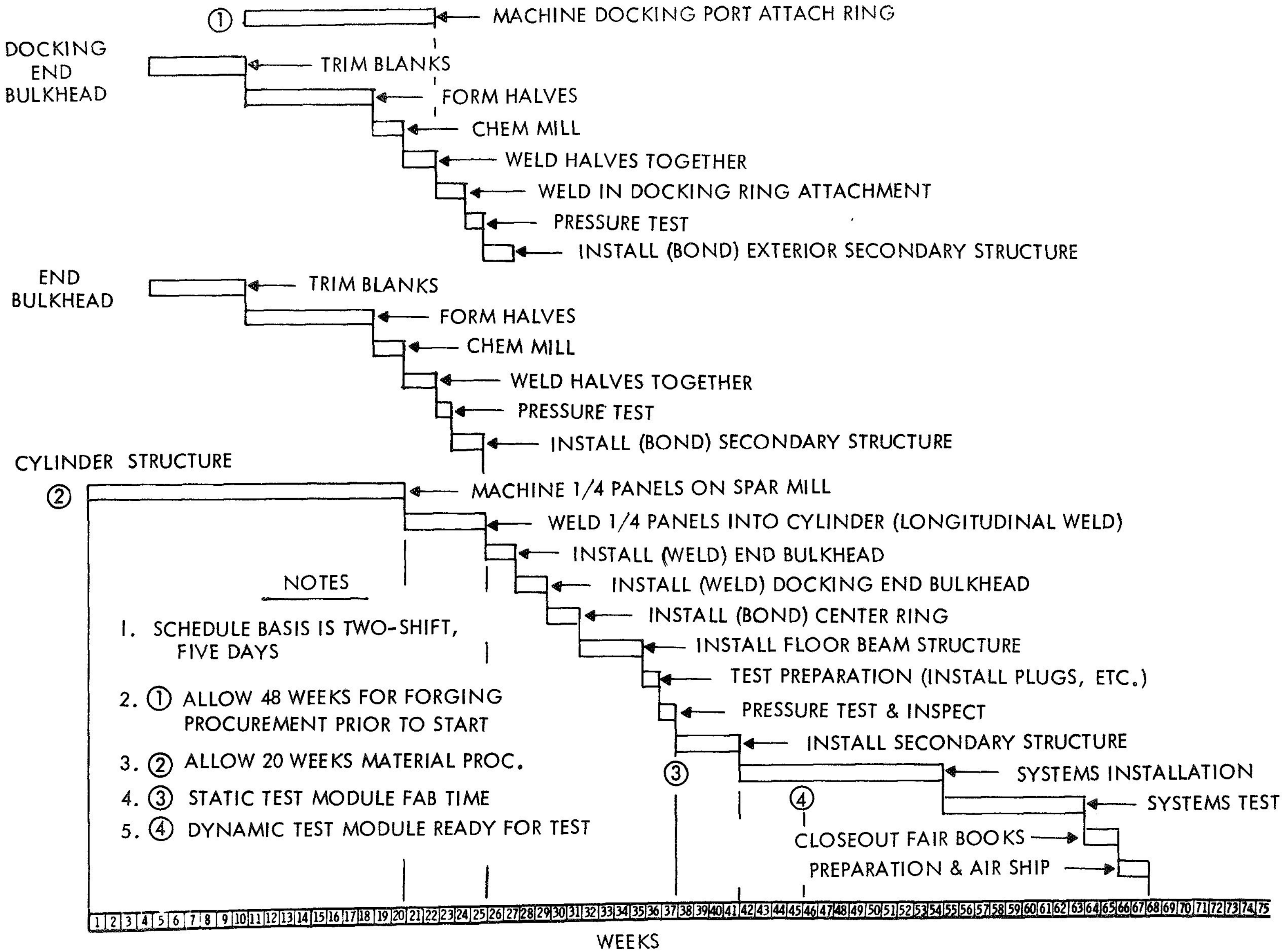
1. Cryo storage only
2. Reused in interface test
3. Subsatellite servicing only

Table 4-3. Derivative Orbiting Lunar Station - Hardware Utilization List - Operational Flight Hardware

	Primary Structure	Secondary Structure	RCS	Environ. Protection	EPS	ECLSS	TMS	G&C	Docking	Crew Habitability
Core Module 1A	1	1	1	1	1	1	1	1	1	1
Core Module 1B	1	1	1	1	1	1	1	1	1	1
Power Module	1	1	1*	1	1	1	1		1	1
Crew Module-CQM #1	1	1		1	1	1	1		1	1
Galley Module	1	1		1	1	1	1		1	1
Crew Module-CQM #3	1	1		1	1	1	1		1	1
Control Module #1	1	1		1	1	1	1		1	1
Control Module #2	1	1		1	1	1	1		1	1
Experiment Module	1	1		1	1	1	1		1	1
Cryo Storage Module #1	1	1	1*	1	1	1	1		1	1
Cryo Storage Module #2	1	1	1*	1	1	1	1		1	1

*Cryogenic storage

FIGURE 4-4. DERIVATIVE ORBITING LUNAR STATION MANUFACTURING FLOW PLAN FOR TYPICAL MODULES



NOTES

1. SCHEDULE BASIS IS TWO-SHIFT, FIVE DAYS
2. ① ALLOW 48 WEEKS FOR FORGING PROCUREMENT PRIOR TO START
3. ② ALLOW 20 WEEKS MATERIAL PROC.
4. ③ STATIC TEST MODULE FAB TIME
5. ④ DYNAMIC TEST MODULE READY FOR TEST

welding of large-diameter bulkheads, and non-destructive inspection techniques. System installation and checkout time spans were based upon experience with the Apollo Command and Service modules. The manufacturing flow plan for the derivative OLS core module shown in Figure 4-5 was developed by a similar analysis for a ten-port core module comprised of two cylinders of different diameters joined together by a transition ring.

The manufacturing composite assembly schedule shown in Figure 4-6, indicates the sequencing and calendar dates for the fabrication and assembly of all major items identified in the HUL. Time spans for the various test articles vary in length to show differences between "typical" and "core" modules. The schedule was developed by working backward from the IOC date of 1 December 1983 given in the OLS study guidelines. The time required for testing and the preferred number of test units and test sequencing are defined together with appropriate dates for Preliminary Design Review, Phase D contract award, and Critical Design Review.

Assumptions used in developing schedules for the derivative OLS are based upon preliminary studies and drawings prepared for the MSS study. The modules are assumed to be 15 feet in diameter and vary from 32 feet to 42 feet in length. Much of the tooling developed for the Apollo and Saturn programs could be adapted for use in the OLS program. An assembly and installations facility similar to the Space Division's Building 290 clean room used on the Apollo program would be required to maintain system cleanliness levels during assembly and test.

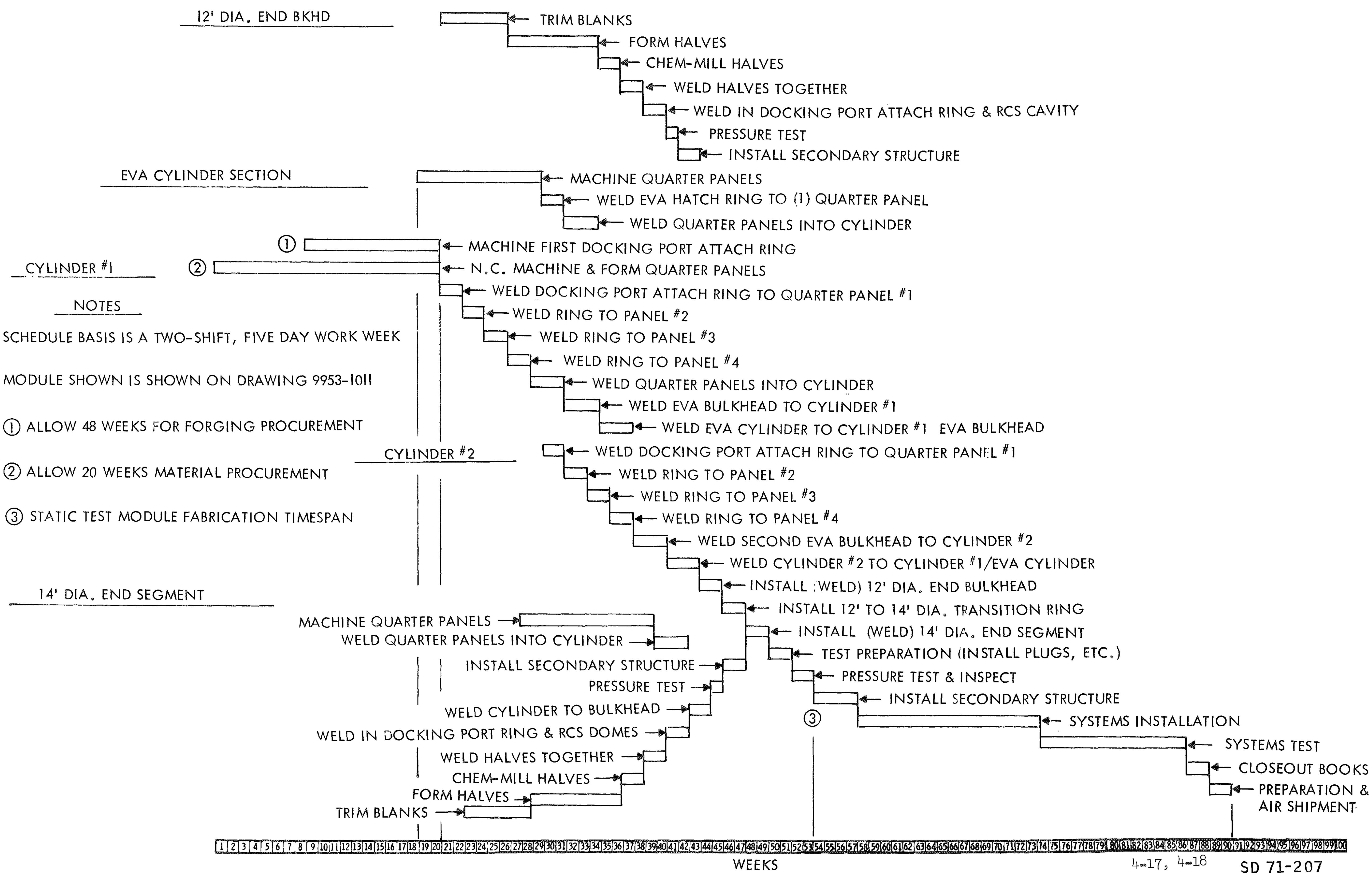
The primary structure of the "typical" module is similar to that of the Saturn S-II, being comprised of machined quarter panel sheets with integral stiffness welded together to form a cylinder. The smaller diameter and length of the modular concept eliminates the need for a Vertical Assembly Building for the stacking of cylinders. Longitudinal joining of full-length quarter panels by use of a welding head carried on an automatic weld truck, or trolley, was assumed to be the method used in the "typical" module buildup. The ends of the "typical" module are comprised of two bulkheads made up of formed halves welded together, with provisions for the attachment of the meteoroid shield bonded to the outside.

The primary structure of the core module closely resembles the assembly method used in the S-II, in that quarter panels are welded together into cylinders and the cylinders then joined to achieve the proper length. This sequence was adopted to allow welding of the docking port attachment ring to the quarter panels in a special fixture prior to joining of the panels. Bonded honeycomb bulkheads are used as pressure bulkheads for the EVA airlock in the center of the module, with end bulkheads similar to the "typical" module being used.

4.3.2 Detailed Program Development Schedule and Plan

The program development schedule shown in Figure 4-7 schedules an integrated set of activities and major milestones for the definition, design, development and production of the derivative OLS. The schedule is predicated on the configurations and subsystems of the derivative OLS described in

FIGURE 4-5. DERIVATIVE OLS MANUFACTURING FLOW PLAN FOR CORE MODULE



NOTES

1. SCHEDULE BASIS IS A TWO-SHIFT, FIVE DAY WORK WEEK
2. MODULE SHOWN IS SHOWN ON DRAWING 9953-1011
3. ① ALLOW 48 WEEKS FOR FORGING PROCUREMENT
4. ② ALLOW 20 WEEKS MATERIAL PROCUREMENT
5. ③ STATIC TEST MODULE FABRICATION TIMESPAN

DERIVATIVE ORBITING LUNAR STATION

MANUFACTURING COMPOSITE ASSEMBLY SCHEDULE

DATE: 02-25-71
PREPARED BY: DEPT. 068

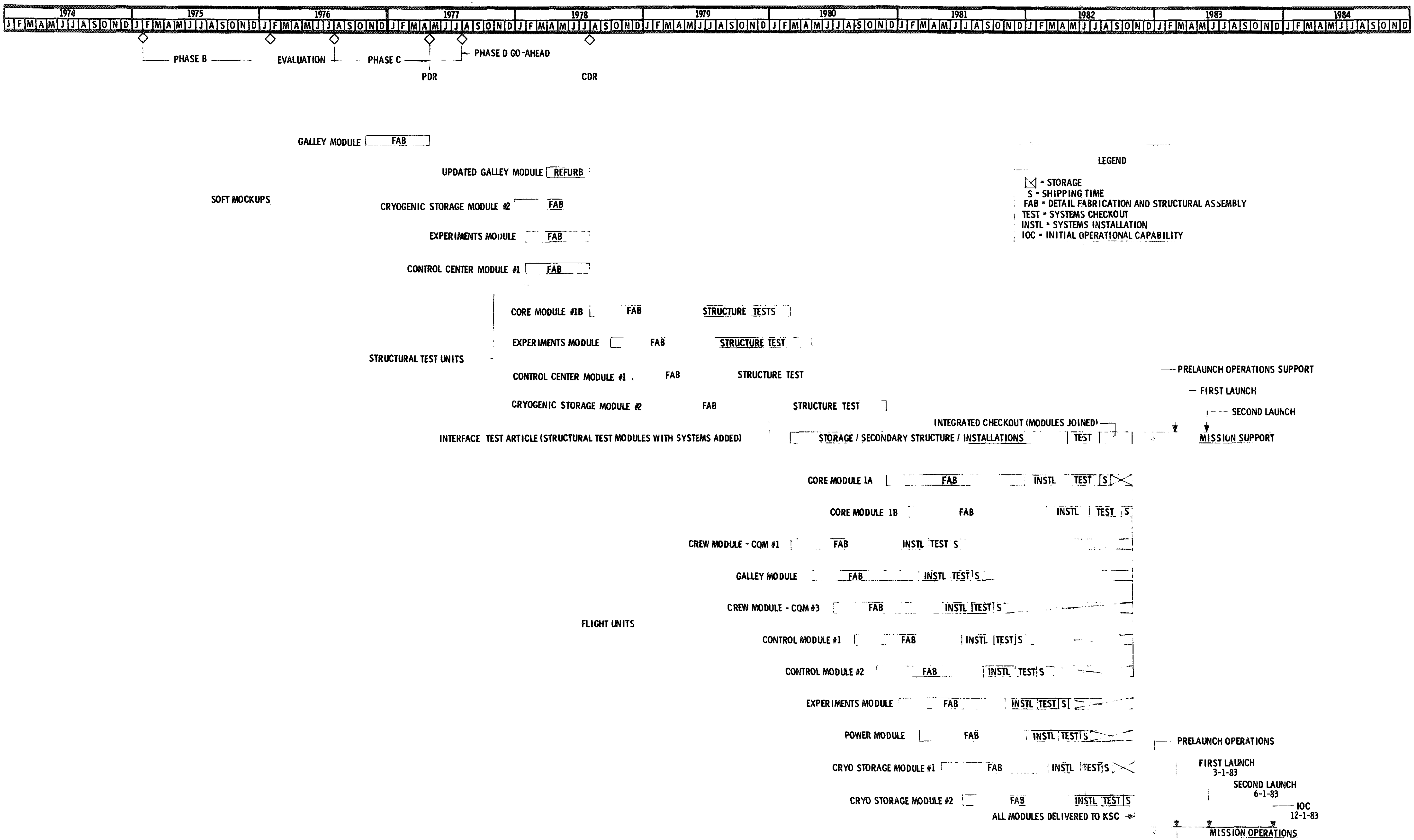
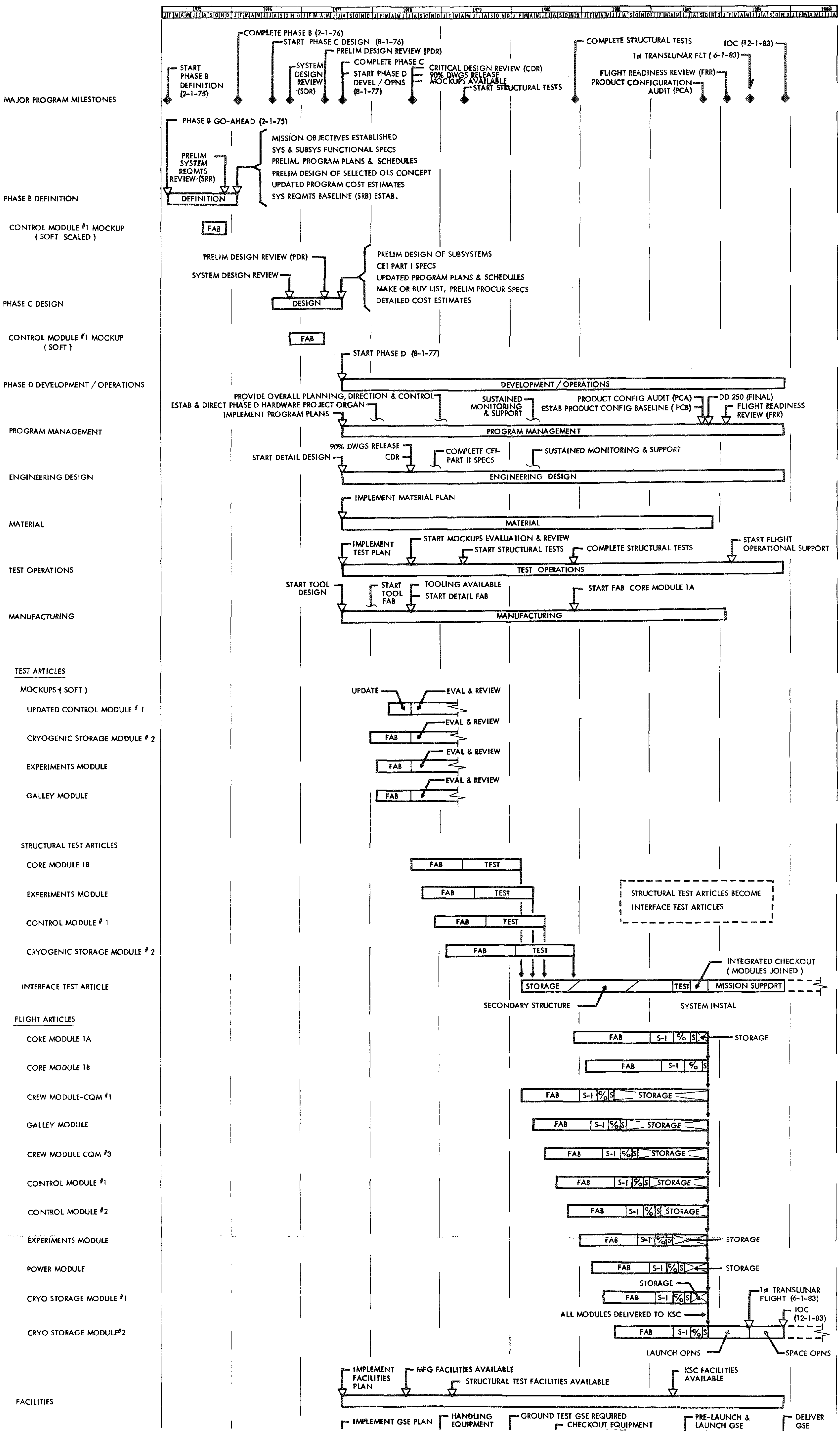


Figure 4-6.



1975 1976 1977 1978 1979 1980 1981 1982 1983 1984
J F M A M J J A S O N D
MAJOR PROGRAM MILESTONES
START PHASE B DEFINITION (2-1-75)
COMPLETE PHASE B (2-1-76)
START PHASE C DESIGN (8-1-76)
SYSTEM DESIGN REVIEW (SDR)
PRELIM DESIGN REVIEW (PDR)
COMPLETE PHASE C
START PHASE D DEVEL / OPNS (8-1-77)
CRITICAL DESIGN REVIEW (CDR)
90% DWGS RELEASE
MOCKUPS AVAILABLE
START STRUCTURAL TESTS
COMPLETE STRUCTURAL TESTS
FLIGHT READINESS REVIEW (FRR)
PRODUCT CONFIGURATION AUDIT (PCA)
1st TRANSLUNAR FLT (6-1-83)
IOC (12-1-83)
PHASE B DEFINITION
PHASE B GO-AHEAD (2-1-75)
PRELIM SYSTEM REQMTS REVIEW (SRR)
DEFINITION
MISSION OBJECTIVES ESTABLISHED
SYS & SUBSYS FUNCTIONAL SPECS
PRELIM. PROGRAM PLANS & SCHEDULES
PRELIM DESIGN OF SELECTED OLS CONCEPT
UPDATED PROGRAM COST ESTIMATES
SYS REQMTS BASELINE (SRB) ESTAB.
CONTROL MODULE #1 MOCKUP (SOFT SCALED)
FAB
PHASE C DESIGN
PRELIM DESIGN REVIEW (PDR)
SYSTEM DESIGN REVIEW
DESIGN
PRELIM DESIGN OF SUBSYSTEMS
CEI PART I SPECS
UPDATED PROGRAM PLANS & SCHEDULES
MAKE OR BUY LIST, PRELIM PROCUR SPECS
DETAILED COST ESTIMATES
CONTROL MODULE #1 MOCKUP (SOFT)
FAB
PHASE D DEVELOPMENT / OPERATIONS
START PHASE D (8-1-77)
DEVELOPMENT / OPERATIONS
PROGRAM MANAGEMENT
PROVIDE OVERALL PLANNING, DIRECTION & CONTROL
ESTAB & DIRECT PHASE D HARDWARE PROJECT ORGAN
IMPLEMENT PROGRAM PLANS
SUSTAINED MONITORING & SUPPORT
PRODUCT CONFIG AUDIT (PCA)
ESTAB PRODUCT CONFIG BASELINE (PCB)
DD 250 (FINAL)
FLIGHT READINESS REVIEW (FRR)
PROGRAM MANAGEMENT
ENGINEERING DESIGN
START DETAIL DESIGN
90% DWGS RELEASE
CDR
COMPLETE CEI-PART II SPECS
SUSTAINED MONITORING & SUPPORT
ENGINEERING DESIGN
MATERIAL
IMPLEMENT MATERIAL PLAN
MATERIAL
TEST OPERATIONS
IMPLEMENT TEST PLAN
START MOCKUPS EVALUATION & REVIEW
START STRUCTURAL TESTS
COMPLETE STRUCTURAL TESTS
START FLIGHT OPERATIONAL SUPPORT
TEST OPERATIONS
MANUFACTURING
START TOOL DESIGN
START TOOL FAB
TOOLING AVAILABLE
START DETAIL FAB
START FAB CORE MODULE 1A
MANUFACTURING
TEST ARTICLES
MOCKUPS (SOFT)
UPDATED CONTROL MODULE # 1
UPDATE
EVAL & REVIEW
CRYOGENIC STORAGE MODULE # 2
FAB
EVAL & REVIEW
EXPERIMENTS MODULE
FAB
EVAL & REVIEW
GALLEY MODULE
FAB
EVAL & REVIEW
STRUCTURAL TEST ARTICLES
CORE MODULE 1B
FAB TEST
EXPERIMENTS MODULE
FAB TEST
CONTROL MODULE # 1
FAB TEST
CRYOGENIC STORAGE MODULE # 2
FAB TEST
STRUCTURAL TEST ARTICLES BECOME INTERFACE TEST ARTICLES
INTERFACE TEST ARTICLE
STORAGE
TEST
MISSION SUPPORT
INTEGRATED CHECKOUT (MODULES JOINED)
SECONDARY STRUCTURE
SYSTEM INSTAL
FLIGHT ARTICLES
CORE MODULE 1A
FAB S-I % S
STORAGE
CORE MODULE 1B
FAB S-I % S
CREW MODULE-CQM #1
FAB S-I % S STORAGE
GALLEY MODULE
FAB S-I % S STORAGE
CREW MODULE CQM #3
FAB S-I % S STORAGE
CONTROL MODULE #1
FAB S-I % S STORAGE
CONTROL MODULE #2
FAB S-I % S STORAGE
EXPERIMENTS MODULE
FAB S-I % S
STORAGE
POWER MODULE
FAB S-I % S
STORAGE
CRYO STORAGE MODULE #1
STORAGE
FAB S-I % S
ALL MODULES DELIVERED TO KSC
1st TRANSLUNAR FLIGHT (6-1-83)
IOC (12-1-83)
CRYO STORAGE MODULE #2
FAB S-I % S
LAUNCH OPNS
SPACE OPNS
FACILITIES
IMPLEMENT FACILITIES PLAN
MFG FACILITIES AVAILABLE
STRUCTURAL TEST FACILITIES AVAILABLE
KSC FACILITIES AVAILABLE
IMPLEMENT GSE PLAN
HANDLING EQUIPMENT
GROUND TEST GSE REQUIRED
CHECKOUT EQUIPMENT
PRE-LAUNCH & LAUNCH GSE
DELIVER GSE

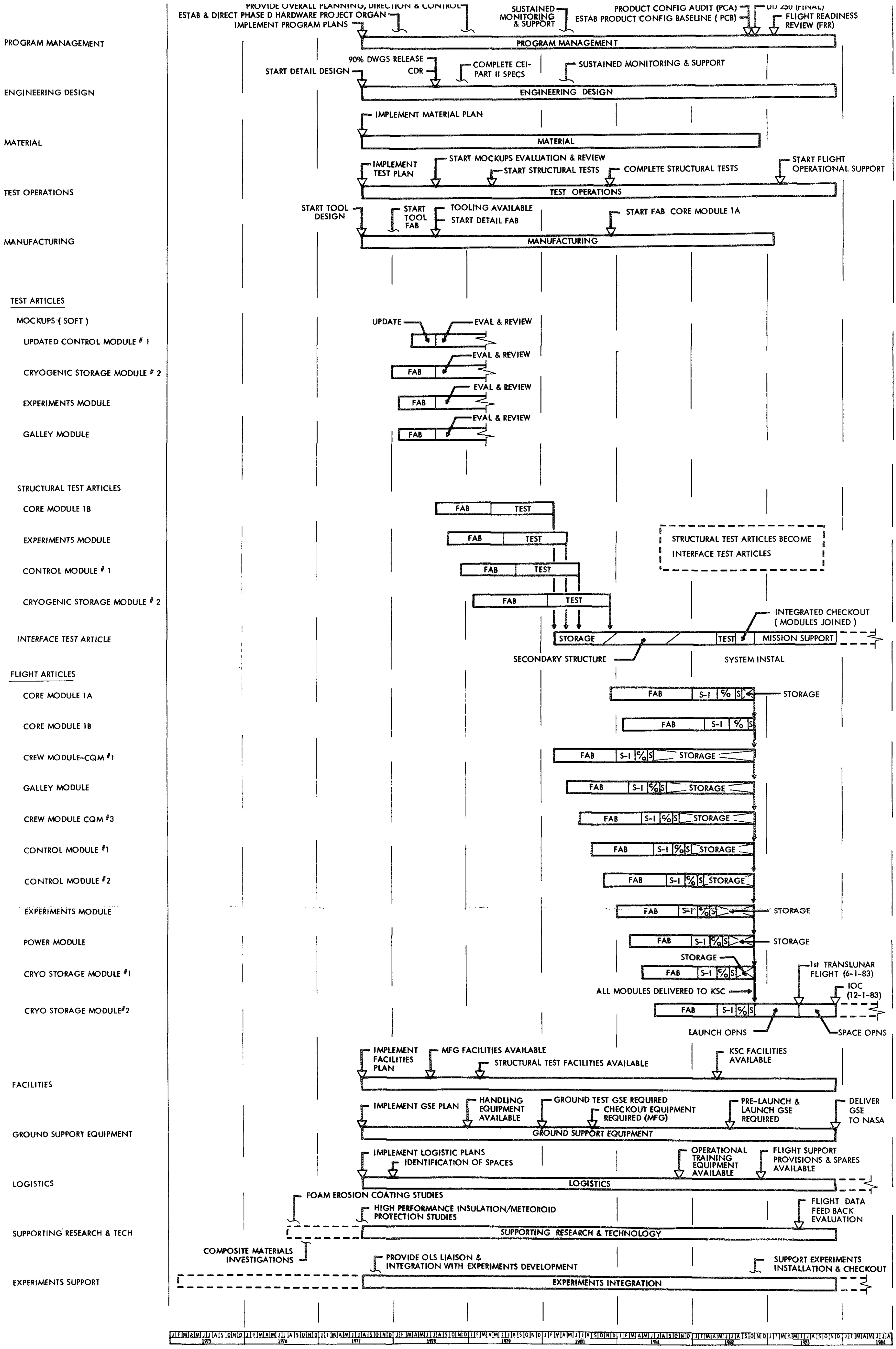


FIGURE 4-7. DERIVATIVE OLS PROGRAM DEVELOPMENT SCHEDULE

Volume V of this report. It presents an orderly evolution of events leading to initiation of lunar operations.

The following ground rules and assumptions were used to provide a common baseline and frame of reference in the preparation of the program development schedule for the derivative OLS.

1. Existing contractor and government facilities will be used; requirements for additional or modified facilities and related equipment will be minimized.

2. A 12-month Phase B definition period is assumed, followed by a 6-month period allowed for NASA evaluation prior to commencing Phase C.

3. A single contract will be awarded for Phase C design and Phase D development/operations. The 12-month Phase C will be followed immediately by the start of Phase D.

4. The manufacturing time spans are based on a selective two-shift, five-day work week; on essentially one set of structural fabrication tooling; and on a sequential buildup concept.

5. The first translunar flight is assumed to take place on 1 June 1983. The IOC data is established six months later on December 1, 1983.

The program development schedule for the derivative OLS shown in Figure 4-7 is based on the assumption that the derivative OLS configuration will be derived from the MSS. Therefore, much of the manufacturing techniques, test approach, logic and data from the MSS will be applicable and applied to the derivative OLS. The program development schedule designates the desired delivery of test articles and flight hardware.

The phasing of the program is as follows:

1. A 12-month Phase B definition will start on February 1, 1975. During this period, the major accomplishments will include:

    a. System requirements baseline (SRB) established

    b. Mission objectives established

    c. System and subsystem functional specifications prepared

    d. Preliminary program plans and schedules prepared

    e. Preliminary design of selected OLS concept

    f. Updated program cost estimates

The completion of the definition study will be followed by a 6-month customer review and evaluation period.

2. Phase C design will start on August 1, 1976 and last for 12 months. Major accomplishments during the design phase study will include:

   a. Preliminary design of subsystems

   b. CEI Part I specifications prepared

   c. System Design Review (SDR)

   d. Updated program plans and schedules

   e. Make-or-buy list prepared

   f. Preparation of procurement specifications

   g. Preliminary Design Review (PDR)

   h. Detailed program cost estimates

3. Phase D development/operations will commence immediately upon the completion of Phase C (August 1, 1977).

4. The total time from the start of Phase D to the first translunar flight (6-1-83) is 70 months. The IOC date is on December 1, 1983.

During the Phase B definition study, a control module #1 soft mockup (scaled) will be fabricated, with completion to coincide with the preliminary System Requirements Review (SRR). A full-size control module is scheduled for fabrication during Phase C to be available for the Preliminary Design Review on May 1, 1977. This mockup will be updated and be available for the Critical Design Review (CDR) during Phase D. Three other soft mockups representing the galley module, experiments module, and cryogenic storage module #2, are also scheduled to be available for the CDR.

The program development schedule depicts the major milestones for each of the principal program functions for the Phase D development/operations. Program plans will be updated and implemented as soon as possible after Phase D go-ahead. Project management will implement the schedule, cost, and technical performance functions. Detailed development and production design effort will begin at the start of Phase D. The Critical Design Review (CDR) is scheduled at 12 months after the start of Phase D, at which time 90 percent of the detail drawings are scheduled for release.

The manufacturing function covers a time span of approximately four and one-half years with fabrication, assembly, system installation, and check-out as applicable for mockups, test articles, and flight hardware. One of the key assumptions used in the preparation of the manufacturing schedule is that the optimum module start rate is one every two months. Time spans differ in length between the test hardware and the flight hardware.

Testing milestones shown on the test operations activity bar depict approximate start and completion dates for the major program tests. Major ground structural tests for the four structural test articles cover a time span of approximately 19 months. As shown on the schedule, significant program saving is realized by the reutilization of the four structural test articles upon completion of structural tests and using them for the interface test article.

The program development schedule shows activity bars along with some of the key milestones for material, facilities, ground support equipment (GSE), logistics, supporting research and technology, and experiments integration. Facilities milestones indicate when manufacturing and operational facilities will be available. GSE milestones indicate when test and launch GSE are required and when handling equipment is available.

Logistics milestones show the need dates for training equipment, provisions, and spares. A typical supporting research and technology activity bar is shown which reflects pacing factors affecting new technology requirements. The experiment integration activity bar depicts the program requirement of providing OLS liaison and integration with experiments development.

An evaluation of the overall program development schedule for the derivative OLS indicates the schedule is feasible. Time spans for the program phases, manufacturing, and test activities, are felt to be realistic with reasonable allowances (time slack) provided for unforeseeable program delays or test failures.

4.4 WORK BREAKDOWN STRUCTURE

The Work Breakdown Structure (WBS) for the derivative OLS shown in Figure 4-8 was jointly developed between NASA/MSC and NR personnel during the course of the study. It presents a hierarchy of levels illustrating the logical separation of a program into hardware elements. The OLS element is expanded into the principal categories of hardware, services, and related work tasks involved in its development down to the major subsystem level (level 5). The WBS provides the frame of reference for the preparation of the program development schedules and plans, hardware utilization lists, and program cost estimates.

The derivative OLS WBS is structured in a manner similar to the representative OLS WBS as well as to WBS's of other current NASA programs. The hardware portion reflects the selected concept of the derivative OLS; i.e., hardware requirements for each of the modules that make up the OLS are identified. To facilitate identification of development (non-recurring) costs and production (recurring) costs, the WBS contains separate breakdowns for test and flight hardware.

#1

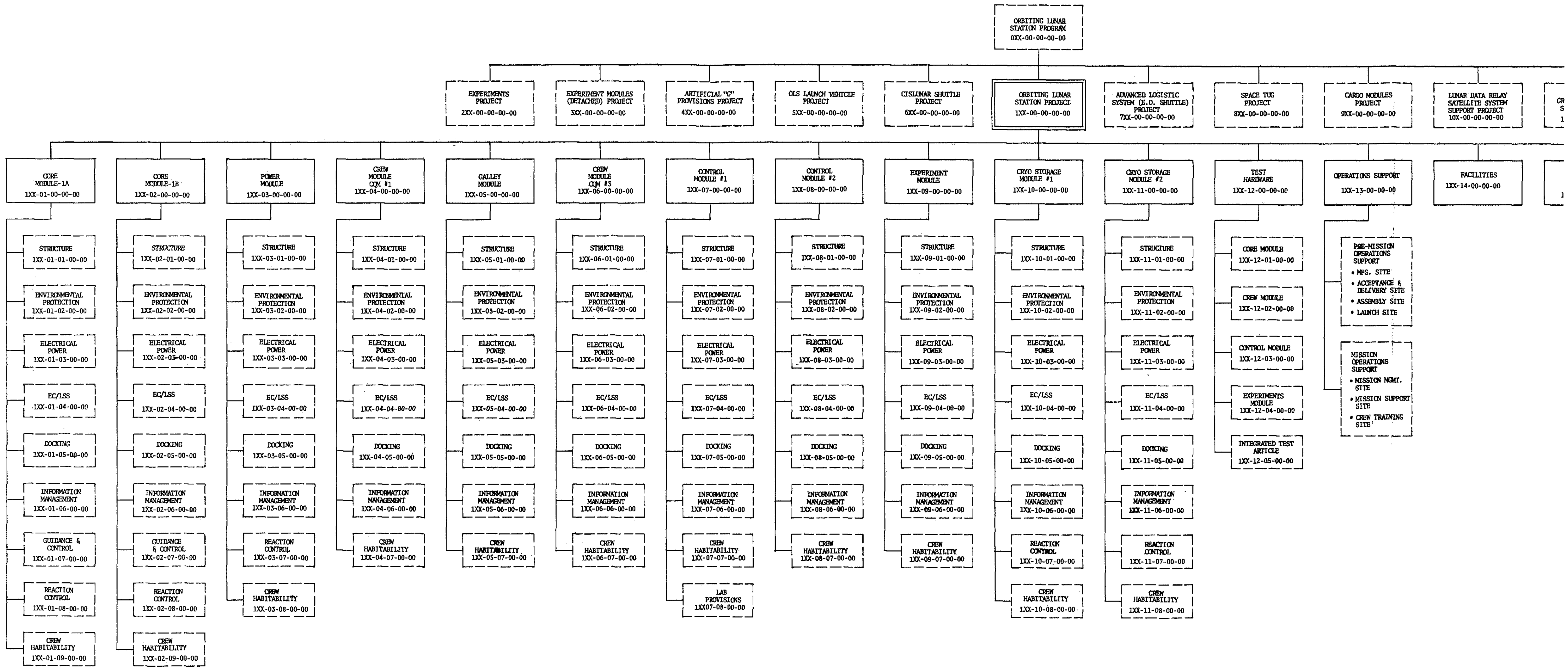
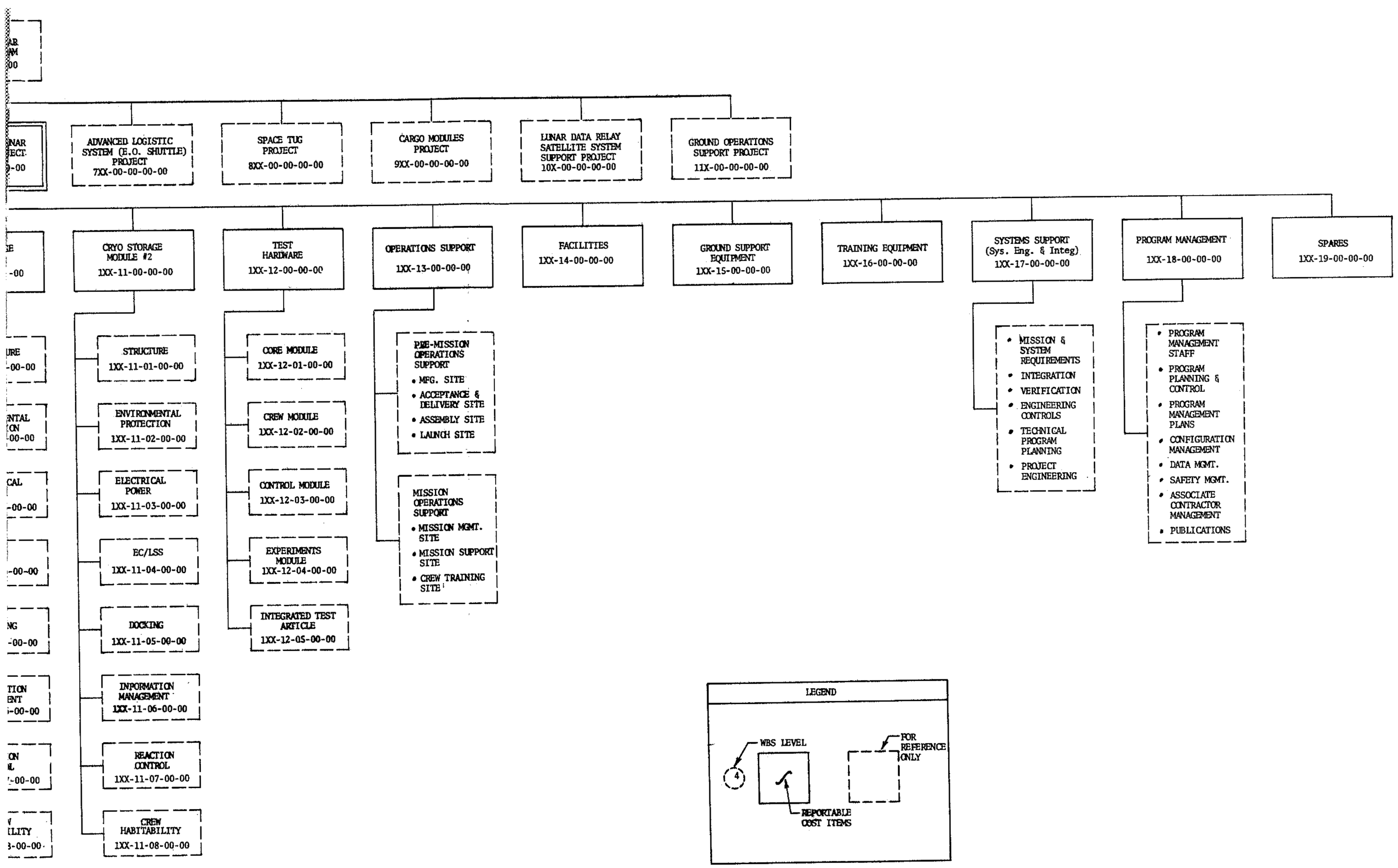


Figure 4-8. Work Breakdown Structure - Derivative OLS

Space Division
North American Rockwell

#2



ructure - Derivative OLS

4.5 PROGRAM COST ESTIMATES

This section contains budgetary and planning costs for the derivative OLS. A technical description of the derivative OLS is presented in Volume V of this report. The data presented herein contains cost, schedule and technical characteristics and was prepared in accordance with the NASA instructions in the Data Requirements Description of DRL, line item 1, enclosed with the statement of work of this study.

The work breakdown structure (WBS), Figure 4-8, provided the frame of reference for estimating and reporting cost at the system element level (WBS level 4). The program development schedule and plan, Figure 4-7, provided the basis for deriving all yearly funding estimates.

4.5.1 Costing Ground Rules

The significant ground rules and assumptions employed in the cost analysis for the OLS program are as follows:

1. Costs reflect GFY 1970 dollars and include all elements of cost through general and administrative (G&A) level. Contractor fee is excluded from this Phase A analysis.

2. Costs are intended for budgetary and planning purposes only and do not constitute a firm commitment on the part of North American Rockwell Corporation.

3. Nonrecurring cost includes design and development, major test hardware, captive and ground test, tooling and special test equipment, test and operations, ground support equipment, facilities, training equipment and simulators and miscellaneous other costs.

4. Recurring production cost includes flight hardware, acceptance test, sustaining tooling and special test equipment, sustaining ground support equipment, launch operations and services, initial flight spares and miscellaneous other costs.

5. A solar-powered modular space station (MSS) has been developed and is operational during Phase D of the OLS program.

6. Module cost estimates are based on estimated dry weights and subsystem complexities allowing for commonality throughout all modules.

7. All cost and schedule requirements are based on the derivative OLS configuration as described in Volume V of this report.

8. The derivative OLS weight statement, contained in Volume V of this report, provided the baseline for all cost projections.

9. Costs excluded from this analysis are as follows:

    a. Supporting research and technology

    b. All consumables

    c. Government facilities

    d. All NASA costs, e.g., MSC, KSC, Mission Control, DRSS/MSFN, crew training, mission support, shuttle operations, etc.

    e. No flight test anticipated or costed, e.g., solar array/deployment

    f. Foods, medical and dental supplies, clothing, personal gear, space suits, EVA equipment, etc.

    g. Subsatellites and scientific instruments

10. Costs are based upon the assumption that the OLS program may not be conducted by the same contractor that conducted the MSS program.

11. Operations support cost covers contractor effort through IOC only.

12. Spares and replacements for 10 years operation will be delivered prior to IOC.

13. The active-active docking adapters are airborne equipment and costed under GSE.

4.5.2 Cost Methodology

The methodology used to estimate the cost of the OLS program was by parametric techniques. A technical comparison was made for each OLS subsystem (WBS level 5) relative to the equivalent Earth Orbital Modular Space Station (MSS) subsystem and complexity factors were derived for development and production. The factors, especially in the development areas, gave consideration to space hardware qualified on the MSS program (reference costing ground rule 5).

Cost estimating relationships (CER's) developed during the conceptual analysis of a MSS provided the baseline subsystem CER's to which OLS complexity and weight factors were applied to derive the costs reported herein. This analysis was conducted under the Space Station Program Phase B definition option period study effort of contract NAS9-9953, and is reported in SD 70-546-1, dated January, 1971.

4.5.3 Summary Cost Estimates

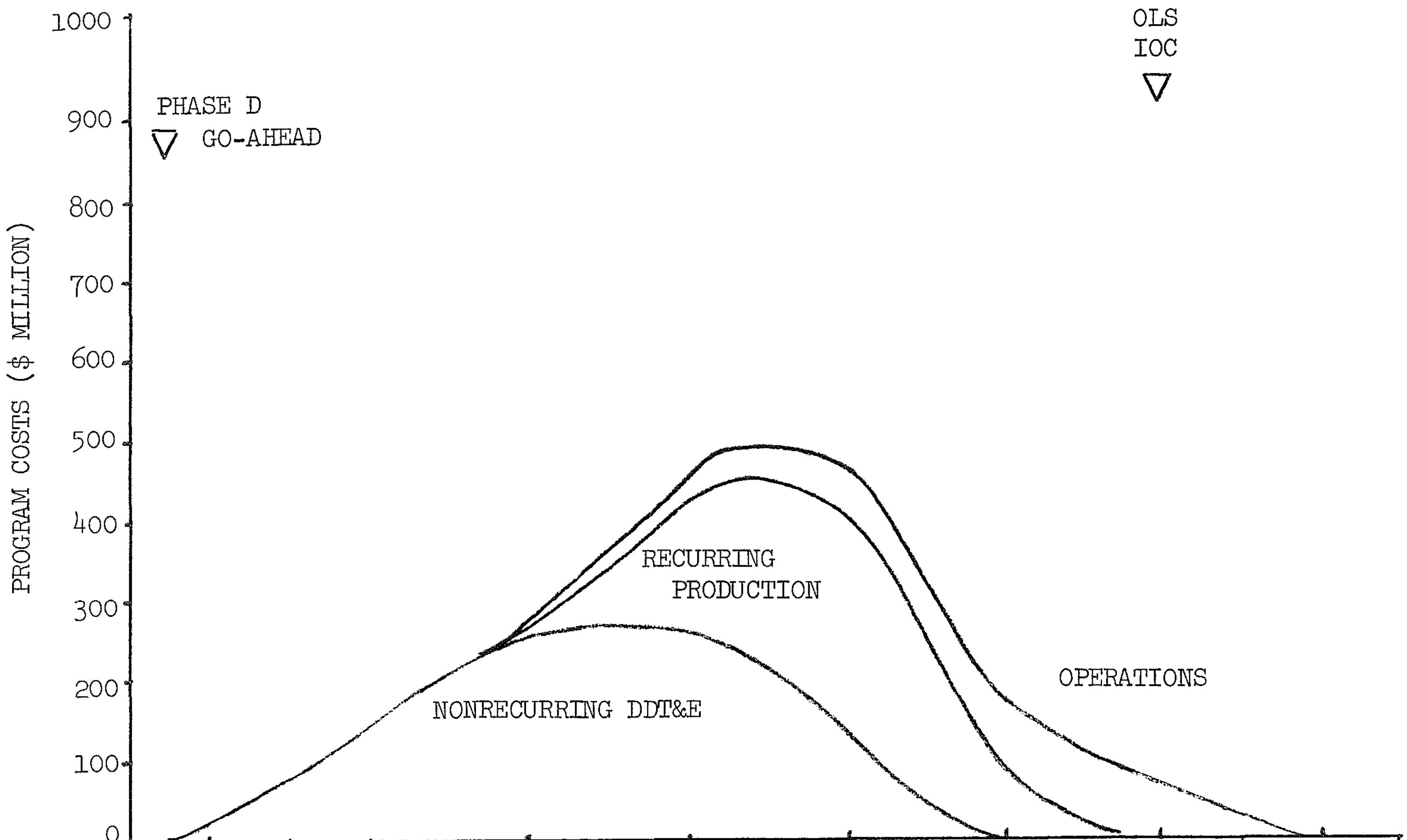
The total estimated cost, excluding contractor fee, for the derivative OLS project elements (WBS level 3) is summarized in Table 4-4 and the funding by GFY is displayed yearly and cumulative on Figures 4-9 and 4-10. Table 4-4 also identifies cost to the system level (WBS level 4) in the nonrecurring and recurring cost categories.

4.5.4 Detail Cost Estimates

The detail cost and schedule data for the derivative OLS configuration are presented on NASA Data Forms A, C, and D. A brief description of the form precedes each set of data.

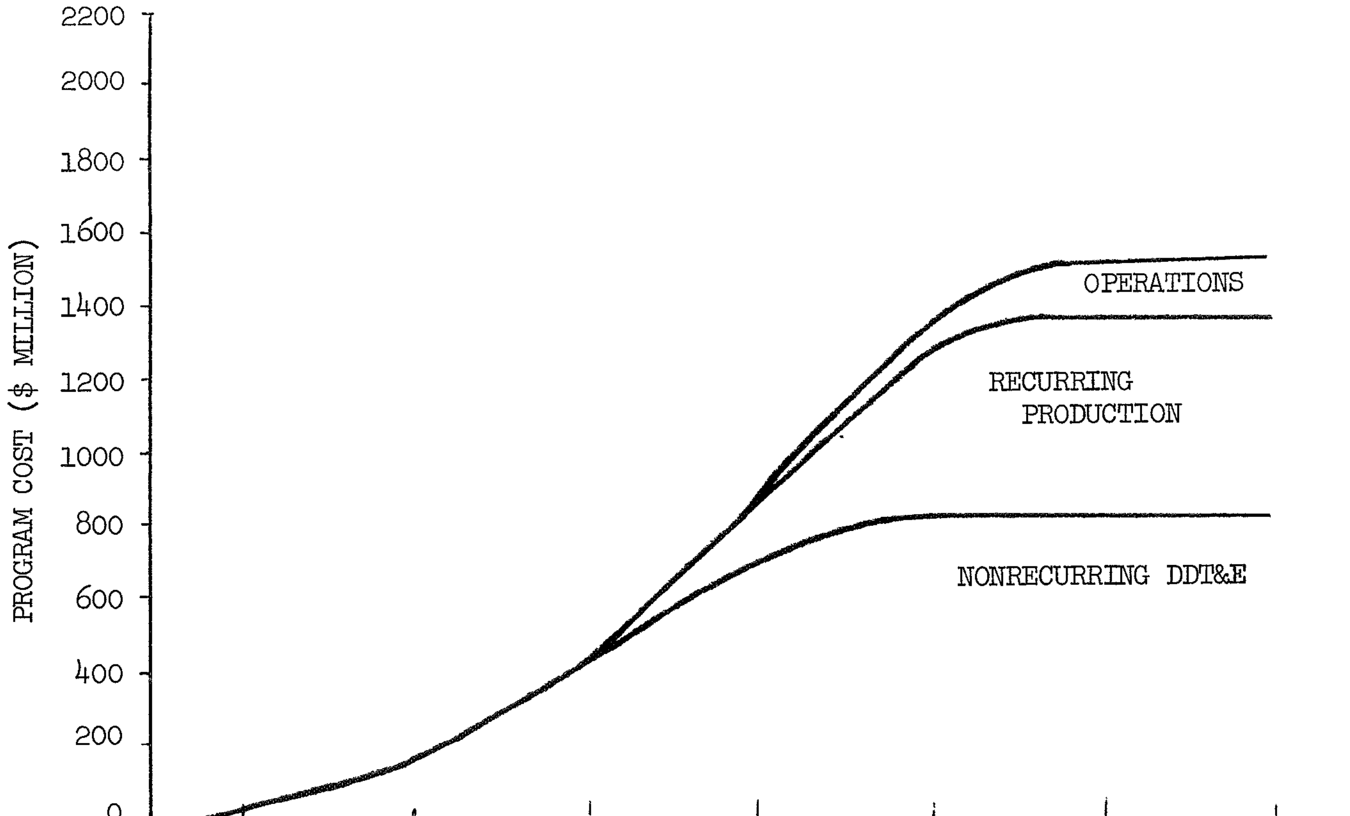
Table 4-4. Cost Summary for Derivative OLS (Millions)

OLS Element	Nonrecurring DDT&E	Recurring First Unit
Core Module - 1A	$ 124.8	$ 63.8
Core Module - 1B	87.1	77.9
Power Module	60.3	82.0
Crew Module - 1	66.0	37.7
Galley Module	17.9	25.1
Crew Module - 3	13.1	30.5
Control Module - 1	42.9	37.6
Control Module - 2	13.9	40.0
Cryo Storage Module - 1	23.4	19.3
Cryo Storage Module - 2	12.3	31.9
Experiment Module	23.2	9.2
Subtotal	484.9	455.0
Major Test Hardware	107.1	-
Subtotal	592.0	455.0
Ground Support Equipment	91.7	8.6
Training Equipment	14.8	--
Facilities	51.5	--
System Support (System Engineering)	39.6	14.1
Program Management	28.3	10.4
Operations Support (through launch)	--	22.6
Spares (initial flight)	--	16.8
Subtotal	$ 817.9	$ 527.5
Operations Support		
Launch through IOC (6 months)		33.8
Spares and Replacements (10 years operation)		200.0
Total Estimated Cost (less fee)	$ 817.9	$ 761.3



GFY	1978	1979	1980	1981	1982	1983	1984	Total
DDT&E	29.2	138.0	256.1	262.0	124.1	8.5		817.9
Production			7.8	153.9	279.6	86.2		527.5
Operations				15.0	64.9	82.4	71.5	233.8
Total	29.2	138.0	263.9	430.9	468.6	177.1	71.5	1579.2

Figure 4-9. Derivative Orbiting Lunar Station GFY Funding Schedule



GFY	1978	1979	1980	1981	1982	1983	1984
DDT&E	29.2	167.2	423.3	625.3	809.4	817.9	817.9
Production			7.8	161.7	441.3	527.5	527.5
Operations				15.0	79.9	162.3	233.8
Total	29.2	167.2	431.1	862.0	1330.6	1507.7	1579.2

Figure 4-10. Derivative Orbiting Lunar Station Cumulative GFY Funding Schedule

Data Form A

Data Form A outlines the total program cost estimate in millions of dollars by WBS items, the time phasing recommended to spread the costs for funding purposes, and a learning index to derive unit costs for recurring items. Separate cost estimates are presented for the design and development activity (nonrecurring costs), and the production and operations activities (recurring costs).

All data necessary to produce the funding schedule - Data Form D, is displayed on Data Form A. An explanation of these requirements is outlined in the following paragraphs.

Learning Index - A numerical index of a learning rate to be applied to the first unit cost of an item to obtain unit costs estimates for subsequent productions. If multiple items are to be produced and no learning index is given, it can be assumed all items are produced at the same cost.

WBS Level - The appropriate level of the item of cost as shown on the WBS.

Number of Units - The quantity of items to be produced.

T_d - The development time (months) or the production time (months) required to design and develop or produce the item. T_d is the duration of cost accrual.

T_s - The lead time (months) measured from the start of cost accrual for the item to the launch milestone

Spread Function - An index number representing a cost distribution curve which the contractor recommends for the time-phasing of costs over the interval T_d; this index number is shown as 50-percent time at 50-percent cost, etc.

DATE ____
PAGE 1 OF 2

COST ESTIMATE DATA FORM A

x NON-RECURRING (DDT & E)
__ RECURRING (PRODUCTION)
__ RECURRING (OPERATIONS)

WBS Level	WBS IDENT. NUMBER a	WBS ITEM NAME b	WBS ITEM COST c	No. of Units d	Refer. Unit e	Learn Index f	T_d g	T_s h	SPREAD FUNC. i	MILESTONE DATE j
3	1XX-00-00-00-00	OLS Project Element	817.9	N/A	N/A	N/A	70	70		6-1-83
4	1XX-01-00-00-00	Core Module - 1A	124.8				58	70	40/60	6-1-83
4	1XX-02-00-00-00	Core Module - 1B	87.1				58	70	40/60	6-1-83
4	1XX-03-00-00-00	Power Module	60.3				58	70	40/60	6-1-83
4	1XX-04-00-00-00	Crew Module - 1	66.0				58	70	40/60	6-1-83
4	1XX-05-00-00-00	Galley Module	17.9				58	70	40/60	6-1-83
4	1XX-06-00-00-00	Crew Module - 3	13.1				58	70	40/60	6-1-83
4	1XX-07-00-00-00	Control Module - 1	42.9				58	70	40/60	6-1-83
4	1XX-08-00-00-00	Control Module - 2	13.9				58	70	40/60	6-1-83
4	1XX-09-00-00-00	Experiment Module	23.2				58	70	40/60	6-1-83
4	1XX-10-00-00-00	Cryo Storage Module - 1	23.4				58	70	40/60	6-1-83
4	1XX-11-00-00-00	Cryo Storage Module - 2	12.3				58	70	40/60	6-1-83
4	1XX-12-00-00-00	Test Hardware	107.1				48	58	40/60	6-1-83
4	1XX-14-00-00-00	Facilities	51.5				57	70	60/40	6-1-83

DATE ________
PAGE 2 OF 2

COST ESTIMATE DATA FORM A

x NON-RECURRING (DDT & E)
__ RECURRING (PRODUCTION)
__ RECURRING (OPERATIONS)

WBS Level	WBS IDENT. NUMBER a	WBS ITEM NAME b	WBS ITEM COST c	No. of Units d	Refer. Unit e	Learn Index f	T_d g	T_s h	SPREAD FUNC. i	MILESTONE DATE j
4	1XX-15-00-00-00	Ground Support Equipment	91.7	N/A	N/A	N/A	49	60	40/60	6-1-83
4	1XX-16-00-00-00	Training Equipment	14.8				51	60	40/60	6-1-83
4	1XX-17-00-00-00	System Support (Sys. Engineering)	39.6				58	70	40/60	6-1-83
4	1XX-18-00-00-00	Program Management	28.3				58	70	40/60	6-1-83

DATE ______
PAGE 1 OF 2

COST ESTIMATE DATA FORM A

___ NON-RECURRING (DDT & E)
_X_ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)

WBS Level	WBS IDENT. NUMBER a	WBS ITEM NAME b	WBS ITEM COST c	No. of Units d	Refer. Unit e	Learn Index f	T_d g	T_s h	SPREAD FUNC. i	MILESTONE DATE j
3	1XX-00-00-00-00	OLS Project Element	527.5				39	39		6-1-83
4	1XX-01-00-00-00	Core Module - 1A	63.8	1	1	90	21	30	40/60	6-1-83
4	1XX-02-00-00-00	Core Module - 1B	77.9	1	1	90	21	27	40/60	6-1-83
4	1XX-03-00-00-00	Power Module	82.0	1	1	90	16	25	40/60	6-1-83
4	1XX-04-00-00-00	Crew Module - 1	37.7	1	1	90	16	39	40/60	6-1-83
4	1XX-05-00-00-00	Galley Module	25.1	1	1	90	16	37	40/60	6-1-83
4	1XX-06-00-00-00	Crew Module - 3	30.5	1	1	90	16	35	40/60	6-1-83
4	1XX-07-00-00-00	Control Module - 1	37.6	1	1	90	16	33	40/60	6-1-83
4	1XX-08-00-00-00	Control Module - 2	40.0	1	1	90	16	31	40/60	6-1-83
4	1XX-09-00-00-00	Experiment Module	9.2	1	1	90	16	29	40/60	6-1-83
4	1XX-10-00-00-00	Cryo Storage Module - 1	19.3	1	1	90	16	27	40/60	6-1-83
4	1XX-11-00-00-00	Cryo Storage Module - 2	31.9	1	1	90	16	25	40/60	6-1-83
4	1XX-13-00-00-00	Pre-Mission Operations	22.6				16	16	40/60	6-1-83
4	1XX-15-00-00-00	Sustaining GSE	8.6				11	11	50/50	6-1-83

DATE ______
PAGE 2 OF 2

COST ESTIMATE DATA FORM A

___ NON-RECURRING (DDT & E)
_X_ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)

WBS Level	WBS IDENT. NUMBER a	WBS ITEM NAME b	WBS ITEM COST c	No. of Units d	Refer. Unit e	Learn Index f	T_d g	T_s h	SPREAD FUNC. i	MILESTONE DATE j
4	1XX-17-00-00-00	Systems Support (Sys. Engineering)	14.1	N/A	N/A	N/A	12	12	40/60	6-1-83
4	1XX-18-00-00-00	Program Management	10.4				12	12	40/60	6-1-83
4	1XX-19-00-00-00	Spares (Initial Flight)	16.8				16	31	40/60	6-1-83

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DATE ______
PAGE 1 OF 1

COST ESTIMATE DATA FORM A

___ NON-RECURRING (DDT & E)
___ RECURRING (PRODUCTION)
_X_ RECURRING (OPERATIONS)

WBS Level	WBS IDENT. NUMBER a	WBS ITEM NAME b	WBS ITEM COST c	No. of Units d	Refer. Unit e	Learn Index f	T_d g	T_s h	SPREAD FUNC. i	MILESTONE DATE j
3	1XX-00-00-00-00	OLS Project Element	233.8	N/A	N/A	N/A	6	6		12-1-83
4	1XX-13-00-00-00	Mission Operations Support	33.8				6	6	50/50	12-1-83
4	1XX-19-00-00-00	Spares (Operational)	200.0				47	49	40/60	12-1-83

Data Form C

Technical Data Form C presents the technical, physical, and mission characteristics which may have a significant effect on the cost of an item.

The technical characteristics include sizing parameters, i.e., total impulse, weight, kwh, volume, etc.; performance parameters; minimum attitude change rates, I_{sp}, etc.; complexity parameters, i.e., number of restarts, number of attitude changes, etc.; reliability parameters, i.e., mission duration, maximum operating distance, etc.

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-00-00-00-00	Orbiting Lunar Station Project	3	8 men 10 years 60 nautical miles 90 degrees 127.2 feet 165,563 pounds	Crew size Mission duration Lunar orbit Orbit inclination Overall length Total dry weight
1XX-01-00-00-00	Core Module 1A	4	29,395 pounds 12/14 feet 41.5 feet 10 3900 cubic feet 6 months	Dry weight Module diameter Module length Docking ports Shirtsleeve volume Independent operation time period
1XX-01-01-00-00	Structure Subsystem	5	10 years - without replacement or extensive reconditioning of primary structure 12/14 feet 41.5 feet Conical Flat 2 Welded skin-stringer 2.0 1.5	Structural Life Diameter Length End bulkhead Pressure bulkhead Pressure isolation area volumes Cylindrical walls Design Ultimate Factors Manned Operations Unmanned Operations Design Yield Factors

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			1,50 1,20 Aluminum Alloy Aluminum Alloy 14.7 psia 7780 pounds	Manned Operations Unmanned Operations Primary structural material Secondary structural material Internal pressure-Design limit Weight
1XX-01-02-00-00	Environmental Protection Sub-System	5	0.9 for 10 years 1310 pounds	Micrometeoroid Protection Probability of no penetration of crew/subsystem components Weight
1XX-01-03-00-00	Electrical Power Subsystem	5	 4KW for 30 days 10KW for 3 days 15KW for 3.5 hours 2KW for 5 days 120/208 vac, 3Ø, 400 Hz 56 vdc 86 cubic feet 9550 pounds	Auxiliary Power Source - Non-regenerative Fuel Cells Emergency Solar Flares Eclipses Premanning Power Distribution Gross Volume Weight
1XX-01-04-00-00	ECLSS	5	11,200 Btu/day/man 1.84 pound/man/day 5.0mm Hg Nominal 65-75 degrees 40 feet/minute	Metabolic load O_2 CO_2 concentration Temperature selectivity All areas Ventilation rate

Temp. Fm. AP-84C, Exp. 5-3-71

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			51.5 pounds/day (N_2/O_2)	Atmospheric leakage makeup
				Thermal Protection
			16.3K Btu/hour	Heat load
			293 square feet	Radiator area
			111 pounds	Weight
				Pumpdown
			360 pounds	Weight
			600 watts	Maximum power
			3310 pounds	Dry weight
1XX-01-05-00-00	Docking Provisions	5	10	Passive ring assembly
				Precontact Velocity
			0.5 fps	Axial
			0.3 fps	Radial
			0.5 degree/second	Angular
				Alignment
			±5 inches	Radial
			±4 degrees	Angular
			±4 degrees	Rotational
			5360 slugs	Capture Mass
			2580 pounds	Weight
1XX-01-06-00-00	Information Management Subsystem	5		Internal Comm./Distribution
			4 KHz each	Voice-up to 35 channels
			4 KHz each	Intercom-up to 15 channels
			4.5 MHz each	CCTV - up to 12 channels
			1 Mbs each	Digital Data Bus, Redundant 2 channels

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
				External Comm.
			S-Band Phased Mono-Pulse	Approach Radar
			20 nautical miles	Minimum Range
			5 feet	Range accuracy
			6.5 MHz Composite	To Lunar surface direct 2 way color TV, 2 way data, 2 way voice
				Displays
			525 TV line, 9 inches x 9 inches	Universal multiformat (color CRT)
			Monitor/Alarm	Discrete event (lights)
				Omni Antennas
			2	Number
			6 inch Flush Mount	Diameter
			8 inch	Length
			2 pounds	Weight
				Data Processor
			1×10^7 "Equiv Add" per second	Computation rate
			16K words (32 bit words)	Operating memory capacity
			1.792×10^6 words	Mass memory capacity
			Up to 5×10^6 bits per second	1/0 unit transfer rate
			Up to 5 RACUs	1/0 port capacity
			1×10^6 bits per second	Archive capacity

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			1 KHz 100 Hz 10 Hz 1 Hz 1270 pounds 23.02 cubic feet	Timing Signals On orbit weight On orbit volume
1XX-01-07-00-00	Guidance & Control Subsys.	5	 ±5 degrees ±1 degree 35 pounds 0.7 cubic feet 30 watts	Attitude Control Premanning Manning Initial On-orbit weight Initial On-orbit volume Electrical power - average
1XX-01-08-00-00	Reaction Control Subsystem	5	10 pounds 4 engine quads/4 engines per quad 4 2 2 2390 pounds	Engine thrust Engine assembly Accumulators Oxygen tanks Hydrogen tanks Nitrogen tanks Dry weight
1XX-01-09-00-00	Crew Habitability	5	1170 pounds	Crew provisions (PLSS and related items)
1XX-02-00-00-00	Core Module 1B	4	23,005 pounds 12/14 feet 41.5 feet 10	Dry weight Module diameter Module length Docking ports

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			3900 cubic feet	Shirtsleeve volume
			6 months	Independent operation time period
1XX-02-01-00-00	Structure Sub-System	5	10 years - without replacement or extensive reconditioning of primary structure	Structural Life
			12/14 feet	Diameter
			41.5 feet	Length
			Conical	End bulkheads
			2	Pressure isolation area volumes
			Welded skin -stringer	Cylindrical walls
				Design Ultimate Factors
			2.0	Manned Operations
			1.5	Unmanned Operations
				Design Yield Factors
			1.50	Manned Operations
			1.20	Unmanned Operations
			Aluminum Alloy	Primary structural material
			Aluminum Alloy	Secondary structural material
			14.7 psia	Internal pressure - design limit
			7780 pounds	Weight
			38,000 pounds	Axial thrust load at -X-Axis Docking port

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-02-02-00-00	Environmental Protection Sub-System	5	 0.9 for 10 years 1310 pounds	Micrometeoroid Protection Probability of no penetration of crew/subsystem components Weight
1XX-02-03-00-00	Electrical Power Subsystem	5	120/208 vac, 3Ø, 400 Hz 56 vdc 44 cubic feet 2890 pounds	Power Distribution Gross volume Weight
1XX-02-04-00-00	ECLSS	5	11,200 Btu/day/man 1.84 pounds/man/day 5.0mm Hg nominal 65-70 degrees F. 40 feet/minute 16.3K Btu/hour 293 square feet 111 pounds 270 pounds 3310 pounds	Metabolic load O_2 CO_2 concentration Temperature Selectivity All areas Ventilation rate Thermal protection Heat load Radiator area Radiator weight Crew Provisions Dry weight
1XX-02-05-00-00	Docking Provisions	5	8 2 4 0.5 fps 0.3 fps 0.5 deg/sec	Passive Ring Assembly Active Ring/Cone Assembly Active/Active Adapter Precontact Velocity Axial Radial Angular

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
				Alignment
			±5 inches	Radial
			±4 degrees	Angular
			±4 degrees	Rotational
			5360 slugs	Capture Mass
			2870 pounds	Weight
1XX-02-06-00-00	Information Management Subsystem	5		Internal Comm./Distribution
			4 KHz each	Voice - up to 35 channels
			4 KHz each	Intercom - up to 15 channels
			4.5 MHz each	CCTV - up to 12 channels
			1 mbs each	Digital data bus, redundant 2 channels
				External Comm.
			S-band phased mono-pulse	Approach radar
			20 nautical miles	Minimum range
			5 feet	Range accuracy
			6.5 MHz composite	To Lunar surface direct 2 way color TV, 2 way data, 2 way voice
				Displays
			525 TV line, 9 inches x 9 inches	Universal multiformat(color CRT)
			Monitor/Alarm	Discrete event (lights)
				Omni Antennas
			2	Number
			6 inch flush mount	Diameter
			8 inch	Length
			2 pounds	Weight

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			 $1x10^7$ "Equiv Add" per second 8K words (32 bit words) Up to $5x10^6$ bits per second Up to 5 RACUs 280 pounds 7.35 cubic feet	Data Processor Computation rate Operating memory capacity 1/0 unit transfer rate 1/0 port capacity On orbit weight On orbit volume
1XX-02-07-00-00	Guidance & Control Subsys.	5	 ± 330 feet ± 950 feet ± 490 feet ± 0.4% (25 fps) ± 5 degrees ± 1 degree ± 2.5 nautical miles altitude 1905 pounds 202.3 cubic feet 562 watts 9000 feet/pound/second	State Vector Estimation (1 sigma) Altitude In-track Cross track Velocity Attitude Control Premanning Manning Station orbit maintenance Initial on-orbit weight Initial on-orbit volume Electrical power - average Total - Momentum storage (CMGs)
1XX-02-08-00-00	Reaction Control Subsystem	5	10 pounds 4 engine quads/4 engines per quad	Engine thrust Engine assembly

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
				Subsatellite provisions
			2	Nitrogen bottles (high pressure)
			2	Nitrogen compressors
			2390 pounds	Dry weight
1XX-02-09-00-00	Crew Habitability	5	270 pounds	Crew provisions
1XX-03-00-00-00	Power Module	4	44.2 feet	Length
			7/14 feet	Diameter
			17,313 pounds	Dry Weight
			1395 cubic feet	Pressurizable volume
			2	Docking ports
1XX-03-01-00-00	Structure Subsystem	5	10 years without replacement or extensive reconditioning of primary structure	Structural Life
			7/14 feet	Diameter
			44.2 feet	Length
			Flat	End bulkheads
			Welded skin-stringer	Cylindrical welds
				Design Ultimate Factors
			2.0	Manned Operations
			1.5	Unmanned Operations
				Design Yield Factors
			1.50	Manned Operations
			1.20	Unmanned Operations

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			Aluminum Alloy Aluminum Alloy 14.7 psia 2735 pounds	Primary structural material Secondary structural material Internal pressure-design limit Weight
1XX-03-02-00-00	Environmental Protection Subsystem		0.9 for 10 years 1023 pounds	Micrometeoroid Protection Probability of no penetration of crew/subsystem components Weight
1XX-03-03-00-00	Electrical Power Subsystem	5	 20 KW 28 KW Solar Array (10K square feet) 120/208 vac, 3Ø 400 Hz, 56 vdc 9570 pounds Batteries 1550 pounds 392 cubic feet 11,120 pounds	Normal Operations Power Average Peak Primary and secondary power source Power distribution Weight Primary and secondary power energy storage Weight Gross volume (excluding solar array Total weight

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PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-03-04-00-00	*EC/LSS	5	11,900 Btu/day/man	Metabolic load
			1.84 pounds/man/day	O_2
			5.0 mm Hg nominal	CO_2 concentration
			60-75 degrees F.	Temperature selectivity
				Pressure control
			14.7 psia	Maximum
			0 psia	Minimum
				Active thermal loop
			275 pounds	Weight
			300 watts	Maximum power
				Thermal protection
			22.6K Btu/Hour	Heat load
			308 square feet	Radiator area
			117 pounds	Weight
	*NOTE: The interior of the Power Module is normally at ambient pressure. However, during periodic servicing and emergency conditions, the interior will be pressurized and a shirtsleeve environment will be provided.			
1XX-03-05-00-00	Docking Provisions	5	1	Passive Ring Assembly
			1	Active Ring/Cone
				Precontact Velocity
			0.5 fps	Axial
			0.3 fps	Radial
			0.5 degree/second	Angular
				Alignment
			± 5 inch	Radial
			±4 degrees	Angular
			±4 degrees	Rotational

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PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			2630 slugs	Capture mass
			670 pounds	Weight
1XX-03-06-00-00	Information Management Subsystem	5		Internal Comm./Distribution
			4 KHz each	Voice - up to 35 channels
			4 KHz each	Intercom - up to 15 channels
			4.5 MHz each	CCTV - up to 12 channels
			1 Mbs each	Digital data bus, redundant 2 channels
				External Comm.
			6.5 MHz composite	To Earth surface, direct to MSFN 2 way color TV, 2 way voice, 2 way data
				To Lunar surface via Lunar satellite or direct 2 way color TV, 2 way data, 2 way voice
			6.5 MHz composite	To CLS: 2 way voice, 2 way data, 2 way ranging
			Experiment Unique	To DET modules; 2 way video, 2 way data, 2 way ranging
				High Gain Antenna
			5 feet diameter	Parabola
			30 feet length	Deployable boom
			Monitor/Alarm	Discrete Events (lights)
				Data Processing
			$1x10^7$ "Equiv Add" per second	Computation rate
			24K words (32 bit words)	Operating memory

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			$1x10^6$ bits/second Up to $5x10^6$ bits/second Up to 8 RACUs 593 pounds 29.44 cubic feet	Archive memory 1/0 unit transfer rate 1/0 port capacity On orbit weight On orbit volume
1XX-03-07-00-00	Reaction Control* Subsystem	5	2,559,000 pound second 92,000 pound second 12,000 pound second 81,000 pound second 2891 pounds 4011 pounds 10 pounds 4 Engine quads/4 engines per quad 2 4 645 pounds	Orbit make-up, total impulse Attitude hold, total impulse Attitude maneuver, total impulse Emergency, total impulse Total cryogenic storage (includes ECLSS and EPS) Oxygen Nitrogen Engine Thrust Engine Assembly Cryogenic Storage Oxygen tanks Nitrogen tanks Weight, dry
	*Note: Propellant for RCS split between the Power Module and the Cryo Storage Modules.			
1XX-03-08-00-00	Crew Habitability	5	135 pounds	Crew provisions

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-04-00-00-00	Crew Module #1	4	12 feet	Module diameter
			31.75 feet	Module length
			2 (1 for storage)	Habitable decks
			350 square feet	Floor area
			2	Docking ports
			3300 $feet^3$	Shirtsleeve volume
			6 months	Independent operation time period
			4	Staterooms
			13,840 pounds	Dry weight
1XX-04-01-00-00	Structure Sub-system	5	10 years - without replacement or extensive reconditioning of primary structure	Structural Life
			12 feet	Diameter
			31.75 feet	Length
			Conical	End bulkheads
			Flat	Pressure bulkhead
			1	Pressure isolation area volumes
			Welded skin-stringer	Cylindrical walls
				Design Ultimate Factors
			2.0	Manned Operations
			1.5	Unmanned Operations
				Design Yield Factors
			1.50	Manned Operations
			1.20	Unmanned Operations

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			Aluminum Alloy Aluminum Alloy 14.7 psia 3860 pounds	Primary structural material Secondary structural material Internal pressure - design limit Weight
1XX-04-02-00-00	Environmental Protection Subsystem	5	 0.9 for 10 years 1236 pounds	Micrometeoroid Protection Probability of no penetration of crew/subsystem components Weight
1XX-04-03-00-00	Electrical Power Subsystem	5	120/208 vac, 3Ø, 400 Hz 56 vdc 11 cubic feet 1000 pounds	Power Distribution Gross Volume Weight
1XX-04-04-00-00	ECLSS	5	11,200 Btu/day/man 1.84 pounds/man/day 5.0 mm Hg nominal 65-75 degrees F. 40 feet/minute 17.42 pound/man/day 12.01 pound/man/day 24.5K Btu/hour 880 square feet 334 pounds 136 pounds	Metabolic load O_2 CO_2 concentration Temperature Selectivity All areas Ventilation rate Potable water usage Wash water usage Thermal protection Heat load Radiator area Weight Backup galley Weight

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			2300 watts	Maximum power (approx. 3 minutes per use)
				Pressure control
			14.7 psia	Maximum
			10 psia	Minimum
			5389 pounds	Dry weight
1XX-04-05-00-00	Docking Provisions	5	1	Passive Ring Assembly
			1	Active Ring/Cone Assembly
				Precontact velocity
			0.5 fps	Axial
			0.3 fps	Radial
			0.5 degrees/second	Angular
				Alignment
			±5 inches	Radial
			±4 degrees	Angular
			±4 degrees	Rotational
			2630 slugs	Capture Mass
			870 pounds	Weight
1XX-04-06-00-00	Information Management Subsystem	5		Internal Comm/Distribution
			4 KHz each	Voice - up to 35 channels
			4 KHz each	Intercom - up to 15 channels
			4.5 MHz each	CCTV - up to 12 channels
			1 Mbs each	Digital data bus, redundant 2 channels
				External Comm.
			6.5 MHz composite	To Earth surface, direct to MSFN 2 way color TV, 2 way voice, 2 way data

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			6.5 MHz composite	To Lunar surface via Lunar satellite or direct, 2 way color TV, 2 way data, 2 way voice
			6.5 MHz composite	To CLS, 2 way voice, 2 way data, 2 way ranging
			Experiment Unique	To DET modules, 2 way video 2 way data, 2 way ranging
				Displays
			525 TV line, 9 inch x 9 inch	Universal multiformat (color CRT)
			Monitor/Alarm	Discrete event (lights)
				High Gail Antenna
			5 feet diameter	Parabola
			30 feet length	Manually deployed boom
				Data Processor
			1×10^7 "Equiv Add" per second	Computation rate
			22K words (32 bits each)	Operating memory capacity
			Up to 5×10^6 bits per second	1/0 unit transfer rate
			Up to 6 RACUs	1/0 port capacity
			690 pounds	On orbit weight
			32.43 cubic feet	On orbit volume
1XX-04-07-00-00	Crew Habitability	5	795 pounds	Personnel Equipment

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PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-05-00-00-00	Galley Module	4	12 feet	Module diameter
			31.75 feet	Module length
			2(1 for storage)	Habitable decks
			350 square feet	Floor area
			2	Docking ports
			3300 $feet^3$	Shirtsleeve volume
			6 months	Independent operation time period
			10,781 pounds	Dry Weight
1XX-05-01-00-00	Structure Sub-system	5	10 years - without replacement or extensive reconditioning of Primary structure	Structural Life
			12 feet	Diameter
			31.75 feet	Length
			Conical	End bulkheads
			Flat	Pressure bulkhead
			1	Pressure isolation area volumes
			Welded skin-stringer	Cylindrical walls
				Design Ultimate Factors
			2.0	Manned Operations
			1.5	Unmanned Operations
				Design Yield Factors
			1.50	Manned Operations
			1.20	Unmanned Operations
			Aluminum Alloy	Primary structural material
			Aluminum Alloy	Secondary structural material
			14.7 psia	Internal pressure - design limit
			3950 pounds	Weight

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-05-02-00-00	Environmental Protection Subsystem	5		Micrometeoroid Protection
			0.9 for 10 years	Probability of no penetration of crew/subsystem components
			1136 pounds	Weight
1XX-05-03-00-00	Electrical Power Subsystem	5	120/208 vac, 3Ø, 400 Hz, 56 vdc	Power Distribution
			11 cubic feet	Gross Volume
			1000 pounds	Weight
1XX-05-04-00-00	ECLSS	5	11,200 Btu/day/man	Metabolic load
			1.84 pound/man/day	O_2
			5.0 mm Hg nominal	CO_2 concentration
				Temperature selectivity
			65-75 degrees F.	All areas
			40 feet/minute	Ventilation rate
				Pressure control
			14.7 psia	Maximum
			10 psia	Minimum
				Thermal Protection
			27.2 K Btu/hour	Heat load
			880 square feet	Radiator area
			334 pounds	Weight
			26.4 pounds/day	Trash disposal (excluding feces)
				Food management
			66 cubic feet	Frozen food storage
			8 pounds/30 minutes	Food preparation (cooking)
			8-12 cubic feet	Refrigerator
			2560 pounds	Dry weight

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-05-05-00-00	Docking Provisions	5	1	Passive Ring Assembly
			1	Active Ring/Cone Assembly
				Precontact velocity
			0.5 fps	Axial
			0.3 fps	Radial
			0.5 degrees/second	Angular
				Alignment
			±5 inches	Radial
			±4 degrees	Angular
			±4 degrees	Rotational
			2630 slugs	Capture mass
			870 pounds	Weight
1XX-05-06-00-00	Information Management Subsystem	5		Internal Comm/Distribution
			4 KHz each	Voice - up to 35 channels
			4 KHz each	Intercom - up to 15 channels
			4.5 MHz each	CCTV - up to 12 channels
			10 KHz each	Entertain - up to 3 channels
			1 Mbs each	Digital data bus, redundant 2 channels
				Displays
			Monitor/Alarm	Discrete event (lights)
				Data Processor
			$1x10^7$ "Equiv Add" per second	Computation rate
			22K words (32 bits each)	Operating memory capacity
			Up to $5x10^6$ bits per second	1/0 unit transfer rate
			Up to 6 RACUs	1/0 port capacity

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			 25 hours 48 hours 2000 hours $3x10^6$ pages 315 pounds 9.02 cubic feet	Other storage requirements Television (4.5 MHz) Entertainment (10 KHz) Voice (4 KHz) Text (microfilm) On orbit weight (station & experiments) On orbit volume
1XX-05-07-00-00	Crew Habitability	5	950 pounds	Personnel equipment
1XX-06-00-00-00	Crew Module #3	4	12 feet 31.75 feet 2 (1 for storage) 350 square feet 2 3300 $feet^3$ 6 months 4 12,365 pounds	Module diameter Module length Habitable decks Floor area Docking ports Shirtsleeve volume Independent operation time period Staterooms Dry weight
1XX-06-01-00-00	Structure Subsystem	5	10 years - without replacement or extensive reconditioning of primary structure 12 feet 31.75 feet	Structural Life Diameter Length

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PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			Conical	End bulkheads
			Flat	Pressure bulkhead
			1	Pressure isolation area volumes
			Welded skin-stringer	Cylindrical walls
				Design Ultimate Factors
			2.0	Manned Operations
			1.5	Unmanned Operations
				Design Yield Factors
			1.50	Manned Operations
			1.20	Unmanned Operations
			Aluminum Alloy	Primary structural material
			Aluminum Alloy	Secondary structural material
			14.7 psia	Internal pressure - design limit
			3860 pounds	Weight
1XX-06-02-00-00	Environmental Protection Subsystem	5		Micrometeoroid Protection
			0.9 for 10 years	Probability of no penetration of crew/subsystem components
			1236 pounds	Weight
1XX-06-03-00-00	Electrical Power Subsystem	5	120/208 vac, 3Ø, 400 Hz, 56 vdc	Power Distribution
			11 cubic feet	Gross Volume
			1000 pounds	Weight
1XX-06-04-00-00	ECLSS	5	11,200 Btu/hour	Metabolic load
			1.84 pound/day/man	O_2
			5.0 mm Hg nominal	CO_2 concentration

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
				Temperature selectivity
			65-75 degrees F.	All areas
			40 feet per minute	Ventilation rate
			17.42 pound/man/day	Potable water usage
			12.01 pound/man/day	Wash water usage
				Pressure control
			14.7 psia	Maximum
			10 psia	Minimum
				Thermal protection
			24.5 Btu/hour	Heat load
			880 square feet	Radiator area
			334 pounds	Weight
			4319 pounds	Dry weight
1XX-06-05-00-00	Docking Provisions	5	1	Passive Ring Assembly
			1	Active Ring/Cone Assembly
				Precontact velocity
			0.5 fps	Axial
			0.3 fps	Radial
			0.5 degrees/second	Angular
				Alignment
			±5 inches	Radial
			±4 degrees	Angular
			±4 degrees	Rotational
			2630 slugs	Capture mass
			870 pounds	Weight

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-06-06-00-00	Information Management Subsystem	5		Internal Comm/Distribution
			4 KHz each	Voice - up to 35 channels
			4 KHz each	Intercom - up to 15 channels
			4.5 MHz each	CCTV - up to 12 channels
			1 Mbs each	Digital data bus, redundant 2 channels
				Displays
			525 TV line, 9 inch x 9 inch	Universal multiformat (color CRT)
			Monitor/Alarm	Discrete event (lights)
				Data Processor
			$1x10^7$ "Equiv Add" per second	Computation rate
			22K words (32 bit words)	Operating memory capacity
			Up to $5x10^6$ bits per second	1/0 unit transfer rate
			Up to 6 RACUs	1/0 port capacity
			335 pounds	On orbit weight
			9.96 cubic feet	On orbit volume
1XX-06-07-00-00	Crew/ Habitability	5	745 pounds	Personnel equipment
1XX-07-00-00-00	Control Module No. 1	4	12 feet	Module diameter
			31.75 feet	Module length
			2 (1 for storage)	Habitable decks
			350 square feet	Floor area
			2	Docking ports

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			3300 $feet^3$	Shirtsleeve volume
			6 months	Independent operation time period
			18,290 pounds	Dry weight
1XX-07-01-00-00	Structure Subsystem	5	10 years - without replacement or extensive reconditioning of primary structure	Structural Life
			12 feet	Diameter
			31.75 feet	Length
			Conical	End bulkheads
			Flat	Pressure bulkhead
			1	Pressure isolation area volumes
			Welded skin-stringer	Cylindrical walls
				Design Ultimate Factors
			2.0	Manned Operations
			1.5	Unmanned Operations
				Design Yield Factors
			1.50	Manned Operations
			1.20	Unmanned Operations
			Aluminum Alloy	Primary structural material
			Aluminum Alloy	Secondary structural material
			14.7 psia	Internal pressure - design limit
			3995 pounds	Weight
1XX-07-02-00-00	Environmental Protection Subsystem	5		Micrometeoroid Protection
			0.9 for 10 years	Probability of no penetration of crew/subsystem components
			4136 pounds	Weight -Includes radiation shelter dry weight

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IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
				Radiation Protection
			25 REM/year	Blood forming organs
			3000 pounds	Dry Weight
1XX-07-03-00-00	Electrical Power Subsystem	5	120/208 vac, 3Ø, 400 Hz, 56 vdc	Power Distribution
			11 cubic feet	Gross volume
			1000 pounds	Weight
1XX-07-04-00-00	ECLSS	5	11,200 Btu/day/man	Metabolic load
			1.84 pounds/man/day	O_2
			5.0 mm Hg nominal	CO_2 concentration
				Temperature selectivity
			65-75 degrees F.	All areas
			40 feet/minute	Ventilation rate
				Pressure control
			14.7 psia	Maximum
			10 psia	Minimum
				Thermal protection
			14.6K Btu/hour	Heat load
			880 square feet	Radiator area
			334 pounds	Weight
				Reconstitution unit
			32 pounds	Weight
			300 watts	Maximum power
				Experiment support
			35 pounds/day	Water recovery
			4000 watts (maximum)	Thermal control
			886 pounds	Dry weight

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-07-05-00-00	Docking Provisions	5	1	Passive Ring Assembly
			1	Active Ring/Cone Assembly
				Precontact velocity
			0.5 fps	Axial
			0.3 fps	Radial
			0.5 degrees/second	Angular
				Alignment
			±5 inches	Radial
			±4 degrees	Angular
			±4 degrees	Rotational
			2630 slugs	Capture mass
			870 pounds	Weight
1XX-07-06-00-00	Information Management Subsystem	5		Internal Comm/Distribution
			4 KHz each	Voice - up to 35 channels
			4 KHz each	Intercom - up to 15 channels
			4.5 MHz each	CCTV - up to 12 channels
			1 Mbs each	Digital data bus redundant 2 channels
				External Comm.
			6.5 MHz composite	To Earch surface, direct to MSFN 2 way color TV, 2 way voice, 2 way data
			6.5 MHz composite	To Lunar surface via Lunar satellite or direct 2 way color TV, 2 way data, 2 way voice
			6.5 MHz composite	To CLS: 2 way voice, 2 way data, 2 way ranging

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			Experiment unique	To DET modules; 2 way video 2 way data, 2 way ranging
				Displays
			525 TV line, 9 inch x 9 inch	Universal multiformat (color CRT)
			15 lines, 50 characters	Discrete alphanumeric (light emitting diode)
			6 digit with decimal	Discrete decimal (digital voltmeter)
			Monitor/Alarm	Discrete event (lights)
			600 lines per minute	Hard-copy test (printer)
				Hard-copy viewer (microfilm)
				Omni Antennas
			3	Number
			6 inch flush mount	Diameter
			8 inch	Length
			2 pounds	Weight
				High Gain Antenna
			5 feet diameter	Parabola
			30 feet length	Manually deployed boom
				Data Processor
			$1x10^7$ "Equiv Add" per second	Computation rate
			75K words (32 bits each)	Operating memory capacity
			512 words	Mass memory capacity
			Up to $5x10^6$ bits per second	1/0 unit transfer rate
			Up to 12 RACUs	1/0 port capacity

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			$1x10^6$ bits per second 1978 pounds 114.4 cubic feet	Archive capacity On orbit weight On orbit volume
1XX-07-07-00-00	Crew Habitability	5	305 pounds	Personnel equipment
1XX-07-08-00-00	Laboratory Provisions	5	5120 pounds 3850 cubic feet 4 KW 7 KW 6 KW 240 square feet	Weight Volume Power* Normal Continuous Peak - 1 minute Maximum - 1 hour Floor area
		*Note:	The power shown may be applied to experiments in the Control Module #1 only, to experiments in the Experiments Module only, or split between experiments in both the Control Module #1 and in the Experiments Module, however, the total power for experiments will never exceed the values shown.	
1XX-08-00-00-00	Control Module No. 2	4	12 feet 31.75 2 (1 for storage) 350 square feet 2 3300 $feet^3$ 6 months 11,340 pounds	Module diameter Module length Habitable decks Floor area Docking ports Shirtsleeve volume Independent operation time period Dry weight

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-08-01-00-00	Structure Subsystem	5	10 years - without replacement or extensive reconditioning of primary structure	Structural Life
			12 feet	Diameter
			31.75 feet	Length
			Conical	End bulkheads
			Flat	Pressure bulkhead
			2	Pressure isolation areas volumes
			Welded skin-stringer	Cylindrical walls
				Design Ultimate Factors
			2.0	Manned Operations
			1.5	Unmanned Operations
				Design Yield Factors
			1.50	Manned Operations
			1.20	Unmanned Operations
			Aluminum Alloy	Primary structural material
			Aluminum Alloy	Secondary structural material
			14.7 psia	Internal pressure - design limit
			3800 pounds	Weight
1XX-08-02-00-00	Environmental Protection Subsystem	5		Micrometeoroid Protection
			0.9 for 10 years	Probability of no penetration of crew/subsystem components
			1136 pounds	Weight
1XX-08-03-00-00	Electrical Power Subsystem	5	120/208 vac, 3Ø. 400 Hz, 56 vdc	Power Distribution
			11 cubic feet	Gross volume
			1000 pounds	Weight

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-08-04-00-00	ECLSS	5	11,200 Btu/day/man	Metabolic load
			1.84 pounds/man/day	O_2
			5.0 mm Hg nominal	CO_2 concentration
				Temperature selectivity
			65-75 degrees F.	All areas
			40 feet/minute	Ventilation rate
				Pressure control
			14.7 psia	Maximum
			10 psia	Minimum
			26.4 pounds/day	Trash disposal (excluding feces)
				Thermal protection
			14.6K Btu/hour	Heat load
			880 square feet	Radiator area
			334 pounds	Weight
			1932 pounds	Dry weight
1XX-08-05-00-00	Docking Provisions	5	1	Passive Ring Assembly
			1	Active Ring/Cone Assembly
				Precontact velocity
			0.5 fps	Axial
			0.3 fps	Radial
			0.5 degrees/second	Angular
				Alignment
			±5 inches	Radial
			±4 degrees	Angular
			±4 degrees	Rotational
			2630 slugs	Capture mass
			870 pounds	Weight

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-08-06-00-00	Information Management Subsystem	5		Internal Comm/Distribution
			4 KHz each	Voice - up to 35 channels
			4 KHz each	Intercom - up to 15 channels
			4.5 MHz each	CCTV - up to 12 channels
			1 Mbs each	Digital data bus, redundant 2 channels
				External Communications
			6.5 MHz composite	To Lunar surface direct, 2 way color TV, 2 way data, 2 way voice
				Displays
			525 TV line, 9 inch x 9 inch	Universal multiformat (color CRT)
			15 lines, 50 characters	Discrete alphanumeric (light emitting diode)
			6 digit with decimal	Discrete decimal (digital voltmeter)
			Monitor/Alarm	Discrete event (lights)
			600 lines per minute	Hard-copy test (printer)
				Hard-copy viewer (microfilm)
				Omni Antennas
			3	Number
			6 inch flush mount	Diameter
			8 inch	Length
			3 pounds	Weight

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
				Data Processor
			$1x10^7$ "Equiv Add" per second	Computation rate
			75 words (32 bit words)	Operating memory capacity
			1.024×10^6 words	Mass memory capacity
			Up to $5x10^6$ bits per second	1/0 unit transfer rate
			Up to 12 RACUs	1/0 port capacity
			1 KHz 100 Hz 10 Hz 1 Hz	Timing Signals
			2222 pounds	On orbir weight (station & experiments)
			135.41 cubic feet	On orbit volume
1XX-08-07-00-00	Crew Habitability	5	380 pounds	Crew items for 8 men/180 days Personnel equipment
1XX-09-00-00-00	Experiments Module	4	176.7 square feet	Floor area
			1	Airlock
			2	Hatches
			5 feet diameter	Side Access
			14 feet diameter	End Access
			11,000 pounds	Initial orbital weight
			15 feet	Module diameter
			24 feet	Module length
			4240 cubic feet	Shirtsleeve volume
			3	Docking Ports

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			110 square feet	Sensor mounting area
1XX-09-01-00-00	Structure Subsystem	5	10 years without replacement or extensive reconditioning of primary structure	Structural Life
			15 feet	Diameter
			24 feet	Length
			Flat	End bulkheads
			Welded skin-stringer	Cylindrical walls
				Design Ultimate Factors
			2.0	Manned Operations
			1.5	Unmanned Operations
				Design Yield Factors
			1.50	Manned Operations
			1.20	Unmanned Operations
			Aluminum Alloy	Primary structural material
			Aluminum Alloy	Secondary structural material
			14.7 psi	Internal pressure - design limit
			8080 pounds	Weight (includes instruments & sub-satellites)
			38,000 pounds	Axial thrust load at docking ports
1XX-09-02-00-00	Environmental Protection Subsystem	5	57 degrees F.	Dew point
			0.9 for 10 years	Probability of no micrometeoroid penetration of crew/subsystem components
			57 degrees F.	Minimum internal surface temp.
			850 pounds	Dry weight

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-09-03-00-00	Electrical Power Subsystem	5	 4 KW 7 KW for 1 minute 6 KW for 1 hour 840 pounds	Normal Operations Power Average Peak Maximum Weight
1XX-09-04-00-00	EC/LSS		11,900 Btu/day/man 1.84 pound/man/day 5 mm Hg nominal 65-75 degrees F. 60-75 degrees F. 1000 watts 14.7 psia 10 psia 8 to 12 mm Hg 100 pounds	Metabolic load O_2 CO_2 concentration Temperature Control Integral experiments All other areas Sensible heat load for integral experiments Pressure Control Maximum Minimum Humidity Control H_2O partial pressure Dry Weight
1XX-09-05-00-00	Docking Provisions	5	2 1 0.5 fps 0.3 fps 0.5 degrees/second	Passive Ring Assemblies Subsatellite retrieval mechanism Precontact velocity Axial Radial Angular

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			 ±5 inches ±4 degrees ±4 degrees 2630 slugs 1130 pounds	Alignment Radial Angular Rotational Capture mass Weight
1XX-09-06-00-00	Information Management Subsystem	5	1 Mbs	Digital data bus, redundant 2 channels
1XX-10-09-00-00	Crew Habitability	5	2390 pounds 1080 pounds	Personnel equipment Crew station control & panels
1XX-10-00-00-00	Cryo Storage Module #1	4	12 feet 31.75 feet 2 1650 $feet^3$ 7689 pounds	Module diameter Module length Docking ports Pressure volume Dry weight
1XX-10-01-00-00	Structure Subsystem	5	10 years - without replacement or extensive reconditioning of primary structure 12 feet 31.75 feet Toroidal (1) Conical (2) Welded skin-stringer	Structural Life Diameter Length End bulkheads Cylindrical walls

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PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
				Design Ultimate Factors
			2.0	Manned Operations
			1.5	Unmanned Operations
				Design Yield Factors
			1.50	Manned Operations
			1.20	Unmanned Operations
			Aluminum Alloy	Primary structural material
			Aluminum Alloy	Secondary structural material
			3520 pounds	Weight
			38,000 pounds	Axial thrust load at X-Axis docking ports
1XX-10-02-00-00	Environmental Protection Subsystem	5		Micrometeoroid Protection
			0.9 for 10 years	Probability of no penetration of crew/subsystem components
			1136 pounds	Weight
1XX-10-03-00-00	Electrical Power Subsystem	5	120/208 vac, 3Ø, 400 Hz, 56 vdc	Power Distribution
			205 pounds	Weight
1XX-10-04-00-00	ECLSS	5		Thermal Protection
			1.4K Btu/hour	Heat load
			293 square feet	Radiator area
			111 pounds	Weight
1XX-10-05-00-00	Docking Provisions	5	1	Passive Ring Assembly
			1	Active Ring/Cone Assembly
				Precontact velocity

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PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
			0.5 fps	Axial
			0.3 fps	Radial
			0.5 degrees/second	Angular
				Alignment
			±5 inches	Radial
			±4 degrees	Angular
			±4 degrees	Rotational
			2630 slugs	Capture mass
			800 pounds	Weight
1XX-10-06-00-00	Information Management Subsystems	5	1 Mbs each	Digital data bus, redundant 2 channels
			78 pounds	Weight
1XX-10-07-00-00	Reaction Control Subsystem	5		*180 day total impulse
			2,559,000 pounds/second	Orbit make-up
			92,000 pounds/second	Attitude hold
			12,000 pounds/second	Attitude maneuver
			81,000 pounds/second	Emergency
				Total cryogenic storage (includes ECLSS and EPS)
			1445 pounds	Oxygen
			863 pounds	Hydrogen
				Cryogenic Storage Tanks
			1	Oxygen
			3	Hydrogen
			1674 pounds	Weight, dry

*Note: Propellant for the RCS is split between the Power Module and the Cryo Storage Modules.

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-10-08-00-00	Crew Habitability	5	130 pounds	Crew provisions
1XX-11-00-00-00-	Cryo Storage Module No. 2	4	12 feet	Module diameter
			31.75 feet	Module length
			2	Docking ports
			1000 feet^3	Pressure volume
			10,545 pounds	Dry weight
1XX-11-01-00-00	Structure Subsystem	5	10 years - without replacement or extensive reconditioning of primary structure	Structural Life
			12 feet	Diameter
			31.75 feet	Length
			Toroidal (1) Conical (2)	End bulkheads
			Welded skin-stringer	Cylindrical walls
				Design Ultimate Factors
			2.0	Manned Operations
			1.5	Unmanned Operations
				Design Yield Factors
			1.50	Manned Operations
			1.20	Unmanned Operations
			Aluminum Alloy	Primary structural material
			Aluminum Alloy	Secondary structural material
			3520 pounds	Weight
			38,000 pounds	Axial thrust load at X-Axis docking ports

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-11-02-00-00	Environmental Protection Subsystem	5	 0.9 for 10 years 1136 pounds	Micrometeoroid Protection Probability of no penetration of crew/subsystem components Weight
1XX-11-03-00-00	Electrical Power Subsystem	5	120/208 vac, 3Ø, 400 Hz, 56 vdc 205 pounds	Power Distribution Weight
1XX-11-04-00-00	ECLSS	5	 1.4K Btu/hour 293 square feet 111 pounds	Thermal Protection Heat load Radiator area Weight
1XX-11-05-00-00	Docking Provisions	5	1 1 0.5 fps 0.3 fps 0.5 degrees/second ±5 inches ±4 degrees ±4 degrees 5360 slugs 800 pounds	Passive Ring Assembly Active Ring/Cone Assembly Precontact velocity Axial Radial Angular Alignment Radial Angular Rotational Capture mass Weight
1XX-11-06-00-00	Information Management Subsystem	5	1 Mbs each 18 pounds	Digital data bus, redundant 2 channels Weight

PROGRAM - TECHNICAL CHARACTERISTICS, DATA FORM C

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	UNITS OF MEASURE	CHARACTERISTICS
1XX-11-07-00-00	Reaction Control Subsystem	5		*180 day total impulse requirements
			2,559,000 pounds/second	Orbit make-up
			92,000 pounds/second	Attitude hold
			12,000 pounds/second	Attitude maneuver
			81,000 pounds/second	Emergency
				Total cryogenic storage (includes ECLSS and EPS)
			4353 pounds	Oxygen
			863 pounds	Hydrogen
			3675 pounds	Nitrogen
				Cryogenic Storage Tanks
			1	Oxygen
			3	Hydrogen
			1	Nitrogen
				Subsatellite Provisions
			2	Positive expulsion, N_2H_4 tanks
			7811 pounds	N_2H_4
			4590 pounds	Weight, dry
		*Note:	Propellant for the RCS is split between the Power Module and the CryoStorage Modules	
1XX-11-08-00-00	Crew habitability	5	130 pounds	Crew provisions

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Data Form D

Data Form D presents an estimate of the resources by government fiscal year required to accomplish subsequent phases of the OLS program. Separate funding schedules are included for design and development (nonrecurring), production (recurring), and operations (recurring).

These schedules present the summarization of cost estimates at level 4 of the WBS and FIL items into the project level. To accomplish this, the WBS cost estimate at level 4 is time-phased by fiscal year against the proposed development and production plans by using the appropriate spreading function, and the results summarized to produce the funding schedules. Details are contained on cost form A. When the schedule of a lower level item is flexible, the schedule has been adjusted to smooth or minimize the peak funding of the project. Funding schedules for major program items are presented separately for the nonrecurring and recurring costs.

DATE ____
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COST ESTIMATE DATA FORM D

X NON-RECURRING (DDT&E)
__ RECURRING (PRODUCTION)
__ RECURRING (OPERATIONS)

WBS Level	WBS IDENT. NUMBER a	WBS ITEM NAME b	WBS ITEM COST c	GFY '78	GFY '79	GFY '80	GFY '81	GFY '82	GFY '83	GFY '84
3	1XX-00-00-00-00	OLS Project Element	817.9	72.9	286.9	323.5	111.7	22.9		
4	1XX-01-00-00-00	Core Module - 1A	124.8	13.3	51.8	51.5	8.2			
4	1XX-02-00-00-00	Core Module - 1B	87.1	9.2	36.2	36.0	5.7			
4	1XX-03-00-00-00	Power Module	60.3	6.4	25.1	24.9	3.9			
4	1XX-04-00-00-00	Crew Module - 1	66.0	7.0	27.4	27.3	4.3			
4	1XX-05-00-00-00	Galley Module	17.9	1.9	7.4	7.4	1.2			
4	1XX-06-00-00-00	Crew Module - 3	13.1	1.4	5.5	5.4	.8			
4	1XX-07-00-00-00	Control Module - 1	42.9	4.6	17.8	17.7	2.8			
4	1XX-08-00-00-00	Control Module - 2	13.9	1.5	5.8	5.7	.9			
4	1XX-09-00-00-00	Experiment Module	23.2	2.5	9.6	9.6	1.5			
4	1XX-10-00-00-00	Cryo Storage Module - 1	23.4	2.5	9.7	9.7	1.5			
4	1XX-11-00-00-00	Cryo Storage Module - 2	12.3	1.3	5.1	5.1	.8			
4	1XX-12-00-00-00	Test Hardware	107.1	--	8.1	34.8	44.1	20.1		

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COST ESTIMATE DATA FORM D

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X NON-RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)

WBS Level	WBS IDENT. NUMBER a	WBS ITEM NAME b	WBS ITEM COST c	GFY '78	GFY '79	GFY '80	GFY '81	GFY '82	GFY '83	GFY '84
4	1XX-14-00-00-00	Facilities	51.5	6.3	15.7	16.9	10.4	2.2		
4	1XX-15-00-00-00	Ground Support Equipment	91.7	6.9	29.8	37.8	17.2			
4	1XX-16-00-00-00	Training Equipment	14.8	.9	3.7	5.5	4.1			
4	1XX-17-00-00-00	System Support (Sys. Engineering)	39.6	4.2	16.5	16.4	2.5			
4	1XX-18-00-00-00	Program Management	28.3	3.0	11.7	11.8	1.8			

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COST ESTIMATE DATA FORM D

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___ NON-RECURRING (DDT&E)
_X_ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)

WBS Level	WBS IDENT. NUMBER a	WBS ITEM NAME b	WBS ITEM COST c	GFY '78	GFY '79	GFY '80	GFY '81	GFY '82	GFY '83	GFY '84
3	1XX-00-00-00-00	OLS Project Element	527.5			7.8	157.7	282.7	79.3	
4	1XX-01-00-00-00	Core Module - 1A	63.8				15.5	40.4	7.9	
4	1XX-02-00-00-00	Core Module - 1B	77.9				5.8	57.5	14.6	
4	1XX-03-00-00-00	Power Module	82.0				6.2	60.4	15.4	
4	1XX-04-00-00-00	Crew Module - 1	37.7			5.9	31.8			
4	1XX-05-00-00-00	Galley Module	25.1			1.9	18.5	4.7		
4	1XX-06-00-00-00	Crew Module - 3	30.5				20.9	9.6		
4	1XX-07-00-00-00	Control Module 1	37.6				25.7	11.9		
4	1XX-08-00-00-00	Control Module 2	40.0				16.0	24.0		
4	1XX-09-00-00-00	Experiment Module	9.2				1.4	7.8		
4	1XX-10-00-00-00	Cryo Storage Module - 1	19.3				3.0	16.3		
4	1XX-11-00-00-00	Cryo Storage Module - 2	31.9				2.4	23.5	6.0	

COST ESTIMATE DATA FORM D

DATE ______
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___ NON-RECURRING (DDT&E)
_X_ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)

WBS Level	WBS IDENT. NUMBER a	WBS ITEM NAME b	WBS ITEM COST c	GFY '78	GFY '79	GFY '80	GFY '81	GFY '82	GFY '83	GFY '84
4	1XX-13-00-00-00	Pre-Mission Operations	22.6					3.6	19.0	
4	1XX-15-00-00-00	Sustaining GSE	8.6						8.6	
4	1XX-17-00-00-00	Systems Support (Sys. Engineering)	14.1				2.2	7.4	4.5	
4	1XX-18-00-00-00	Program Management	10.4				1.6	5.5	3.3	
4	1XX-19-00-00-00	Spares (Initial Flight)	16.8				6.7	10.1		

COST ESTIMATE DATA FORM D

DATE ______
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___ NON-RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
_X_ RECURRING (OPERATIONS)

WBS Level	WBS IDENT. NUMBER a	WBS ITEM NAME b	WBS ITEM COST c	GFY '78	GFY '79	GFY '80	GFY '81	GFY '82	GFY '83	GFY '84
3	1XX-00-00-00-00	OLS Project Element	233.8				15.0	64.9	82.4	71.5
4	1XX-13-00-00-00	Mission Operations Support	33.8							33.8
4	1XX-19-00-00-00	Spares (Operational)	200.0				15.0	64.9	82.4	37.7

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